ASTRONOMY

APRIL 1977 $1.50

Performance is the First Reason You're Proud to Own a Criterion

In telescopes, "excellence is as excellence does." Our Criterion instruments, with unsurpassed optics, rank among the world's most widely praised, because they perform brilliantly, reliably and with satin-smooth, effortless ease. The more demanding the conditions of use, the more you appreciate the ability of your Criterion to deliver exciting results. Whichever advanced design telescope you select, you get a superbly engineered instrument, guaranteed unconditionally. When you compare the pleasantly surprising prices your find further reason to choose Criterion. Please note that they are not "base" prices, but include everything described AT NO EXTRA COST. Only Criterion's leadership in efficient, modern precision production makes these prices possible.

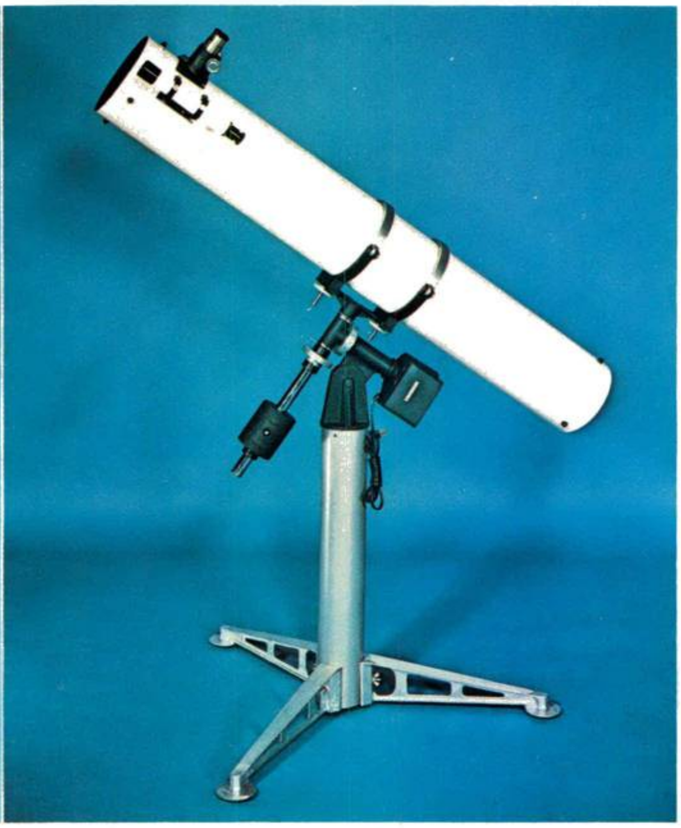
Dynamax® 8 8-Inch Schmidt-Cassegrain

For Spectacular Results—Effortlessly.
Extra Features Without Extra Price.

This "never before" telescope created by Criterion gives you Schmidt-Cassegrain advantages at their best: full 8" aperture, wide field, with flawless resolution, yet weighs only 30 pounds for one-hand portability! It offers unprecedented versatility for viewing, superb telephotography, terrestrial uses, or technical applications. The exquisite optics, combined with super-precise electric drive plus variable drive corrector, combine to insure unsurpassed, unequalled ease of use because the extra features so necessary for superior results are designed-in and built-in... and INCLUDED in the price! ☐ AC, DC, and manual drives (variable, not just solar). You can easily dial in lunar, solar, sidereal, planetary etc. rates while observing for extra long monitoring. ☐ Large 8x50 finderscope has micrometer screw focusing ☐ Toggle switch with pilot light ☐ Engraved setting circles, observable from viewing position ☐ 3 eyepieces included ☐ Star diagonal, latitude adjusters, photo and telextender adaptors, and custom, fitted case. Ready for Total Performance with nothing else to buy!

As described, complete. FOB Hartford, Conn. Shipping wt. 65 lbs. Express charges collect.

$875



Dynascope® RV-6 6-Inch Newtonian

For Exciting Viewing, Superb Value.
Price Includes Built-In,
Precision Electric Drive!

Professionals and astute amateurs and school or college users by the thousands know the breathtaking performance, this pace-setting telescope achieves. ☐ Exquisite optical system includes f8 parabolic aluminized mirror, guaranteed to reach all theoretical limits of resolution and definition ☐ Highly accurate Electric Drive uses regular AC, has smooth, self-acting clutch, permits manual operation ☐ Two 1¼" eyepieces, 70X and 140X, included. (others available) ☐ Highly stable equatorial mount with solid tripod, adjusts easily for any latitude ☐ Engraved setting circles for both right ascension and declination ☐ Tube rotates for adding cameras and comfortable viewing Easy, quick portability ☐ Smooth, brass rack-and-pinion focusing ☐ Handsome, white 50" Bakelite tube maintains perfect collimation ☐ 6x30 finderscope ☐ Fine workmanship throughout.

As described, complete.
FOB Hartford, Conn. Shipping wt. 77 lbs.
Express charges collect, $15 crating charge.

$229.95

Prompt shipment on both models. If you wish, phone us for delivery date.
To place your order, or request literature, write or call:

Criterion Manufacturing Company

Dept.CAS-53 620 Oakwood Ave., W. Hartford, Conn. 06110/Phone: (203) 247-1696
In New York, Robert T. Little, Eastern Sales Manager (212) 834-1888

COSMOS 1977

A new art reprint calendar from ASTRONOMY

Cosmos 1977 carries into its fourth year a tradition started when ASTRONOMY magazine was born — to provide you the most visually stunning view of the universe possible.

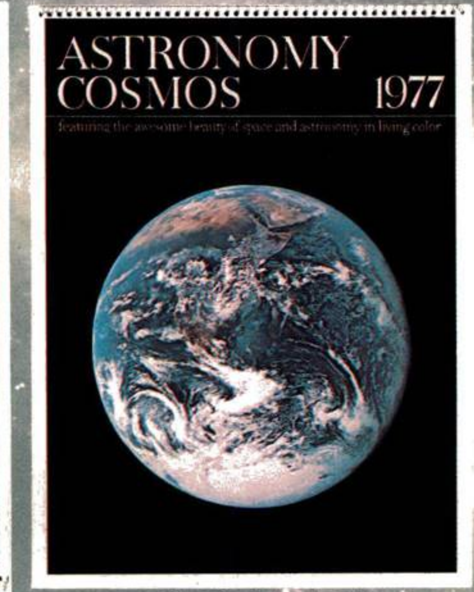
This year's calendar brings our promise to you in its ultimate form. Cosmos 1977 is a collection of 13 full color varnished reproductions of some of the best cosmic art and photographs that have appeared in ASTRONOMY. From the surface of the red planet Mars and glowing tail of comet West, to worlds beyond at the heart of a distant star cluster, the colorful, pictorial universe is displayed in a format that "begs" that the subjects be framed.

Each illustration, printed on coated 80 lb. paper, is surrounded by a 1/4" white border for greater ease in framing. As with last year's calendar, complete framing instructions are provided. Cosmos 1977 is spiral bound and hole punched so that the calendar may be conveniently hung. (Both hole and wire spiral are within the white border away from the illustrations.)

Hallmarks of ASTRONOMY's quality and beauty epitomize this distinctive calendar whether the illustrations are framed immediately or the calendar hung and used throughout the year.

January 1977

S	M	T	W	T	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					


ASTRONOMY
COSMOS 1977
featuring the awesome beauty of space and astronomy in living color

Size: 8 3/4" x 11 3/4"

only $4.50 each

(Include 75¢ per order for shipping & handling.)

Exciting Features Include:

- **Full color, varnished art & photos**
- **Framing instructions provided**
- **Punched for hanging**
- **Planet oppositions & special sky events noted**
- **Room to jot birthdays and other appointments**
- **1977 Calendar**

ASTRONOMY
411 E. Mason St., 6th Floor,
Milwaukee, WI 53202

Please send me __________copies of ASTRONOMY's Cosmos 1977.
Enclosed is __________(including 75c for shipping and handling).

Send check or money order to:
ASTRONOMY
411 E. Mason St., 6th Floor
Milwaukee, WI 53202

Date: __________

Name __________ (Please Print)

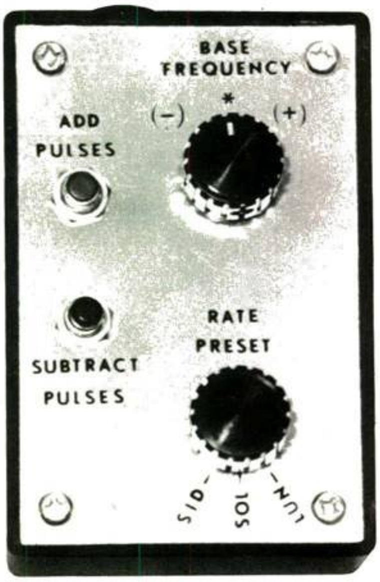
Address __________

City __________ State/Prov. __________ Zip __________

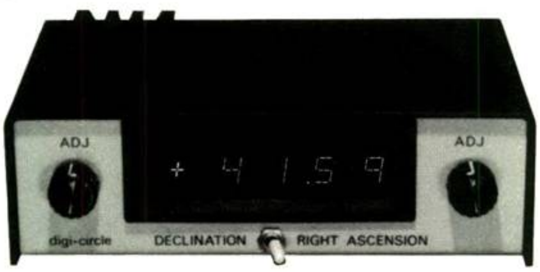
S&S OptikA, Ltd.

PRESENTS THE
MODULAR CONCEPT IN TELESCOPE ELECTRONICS

DIGI-GUIDE™—This ultra linear drive corrector makes your telescope drive at exactly the correct rate for viewing or photography. Use your 12 v.d.c. car battery for field use or 115 v.d.c. line current from your home. Either way tracking is perfect. Comes complete with 15 foot 12 volt cords; solar, sidereal, and lunar preset rate selector. The hand held control box is shown here for an example of the unusual quality and beauty of this instrument. NASA specs. Premium quality. 25 watts output, fused to 15 watts. Quality far surpassing price—only $109.00 postpaid. Write for specs.



DIGI-CIRCLE™—This digital read-out setting circle set allows you to utilize far more of your observing time by finding objects much faster and with far less fuss. This advanced electronics package matches the above Digi-Guide in style, finish and premium quality. Prices depend on the telescope you are using. Write or call for information.



NOTE: IF YOU ARE PLANNING TO BUY A CELESTRON 5, 8 OR 14 IN THE NEAR FUTURE, ASK ABOUT OUR SPECIAL PACKAGE PRICES AND LOW COST PAYMENT PLANS.

S&S OptikA, Ltd.
3853 South Broadway
Englewood, Colorado 80110
Phone (303) 789-1089

CELESTRON • UNITRON • NIKON

ASTRONOMY

The World's Most Beautiful Astronomy Magazine

April 1977 Vol. 5, No. 4

PUBLISHER and EDITORIAL DIRECTOR
Stephen A. Walther

EDITORIAL
Managing Editor
Penny Oldenburger

Technical Editor
Richard Berry

Associate Editor
Henry J. Phillips

Staff Writer and Astro-News Editor
Mary Jane Lamers

Contributing Editors
James Mullaney
James E. Oberg
Gerrit L. Verschuur

GRAPHICS
Production Manager
David A. Schwartz

Staff Artist
Mark Paternostro

CIRCULATION
Subscriber Relations
Jodi Groth
Rosemary L. Pickart

COMMUNICATION
Information Officer
Penny Oldenburger

6 SUPERNOVAE!
by Jeanne Hopkins

18 ASTRONOMERS IN SPACE: Part 1
by James Oberg

26 SKY ALMANAC
Lunar Eclipse Highlights April

28 PLANET FINDER — APRIL 1977

34 EQUIPMENT ATLAS
Building A 6" Reflector
Part 1: Grinding the Mirror
by Alan P. Witzgall

42 GAZER'S GAZETTE
Observing the Outermost Planets
by Henry J. Phillips

46 PHOTOGRAPHY IN ASTRONOMY
Printing Your Astrophotographs
Part 3: Nebulae
by Richard Berry

55 IN FOCUS

58 ASTRONOMY REVIEWS

61 ASTRO-NEWS

66 ASTRO-MART

71 GUIDE TO BACK ISSUES

73 APRIL STAR DOME
by James Mullaney and Henry J. Phillips

75 Close-Up on the Leo/Leo Minor Region

Cover

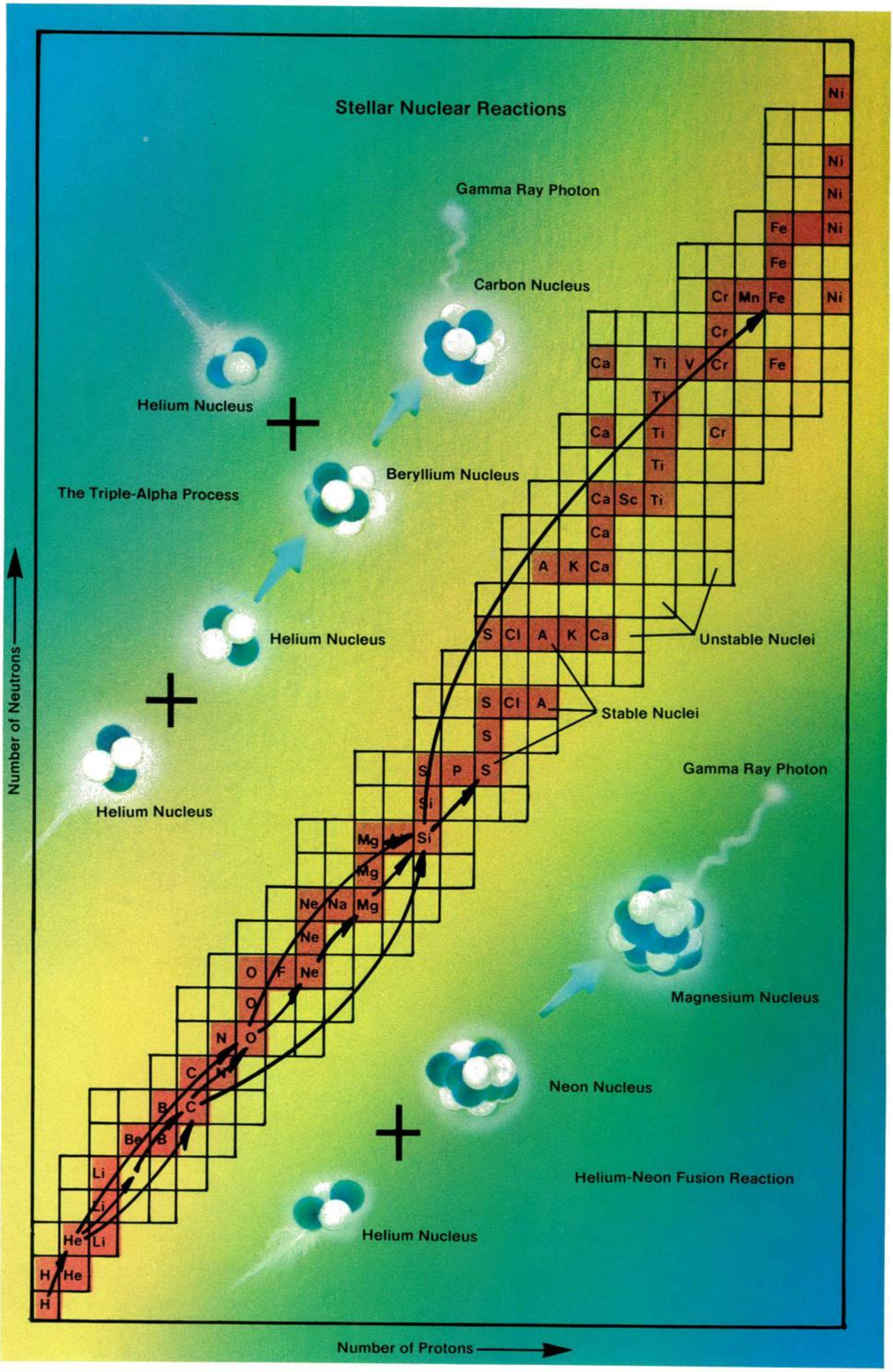
Early risers will have no problem seeing the Trifid nebula in Sagittarius, well up in the eastern sky before morning twilight. Our cover photograph required a 25 minute exposure on High Speed Ektachrome, using a home built cold camera at the focus of a 16 inch f/6 Newtonian. ASTRONOMY this month brings you the story of supernovae — the catastrophic death of giant stars, and a preview of Space Shuttle astronomers of the fast-approaching 1980s who will go into space to make their observations. And in this issue, we are beginning a new Equipment Atlas series on how you can build your own six inch reflector — an often forgotten way to "obtain" a fine telescope. Photograph by Orien Ernest.

Published monthly by AstroMedia Corp., 411 E. Mason St., 6th Floor, Milwaukee, WI 53202. Copyright © 1977 by AstroMedia Corp., all rights reserved. No part of this issue may be reproduced by any mechanical, photographic or electronic process, or otherwise copied for public or private use without written permission of the publisher. Second class postage paid at Milwaukee, WI and at additional mailing offices. POSTMASTER: When undeliverable, send form 3579 to publisher. Direct all new subscriptions, changes of address, renewals and subscription bill payments only to ASTRONOMY, Circulation Services, P.O. Box 186, Westchester, IL 60153 and allow six to eight weeks for new subscriptions and changes of address to take effect. To speed service on subscription correspondence, complaints, photographs, slides, manuscripts and editorial correspondence write ASTRONOMY, 411 E. Mason St., 6th Floor, Milwaukee, WI 53202. Telephone (414) 276-2689. Due to the limited availability of back issues, new subscriptions must start with the most current month's issue. Cover price, $1.50. Subscription price: 1 year, $12.00. Canada & Mexico: add $3.00 per year. All other foreign: add $6.00 per year. Additional office staff: William Stanfield, Production Assistant; Katherine King, Editorial Assistant; Judy O'Dair, Editorial Secretary; Stephanie Kiel, Administrative Assistant; Nancy Faustmann, Executive Secretary and Bulk Copy Sales. Accountant: Peter Trabbold. Consulting Editors: Thomas C. Bretl, John Harmon. Contributing Artists: John W. Clark, Victor Costanzo, Adolf Schaller. ADVERTISING REPRESENTATIVES: Western Region — J.E. Publisher's Representative Co., 8732 Sunset Blvd., 4th Floor, Los Angeles, CA 90069; (213) 659-3810. Eastern Region — J.E. Publishers' Representative Co., 527 Madison Ave., New York, NY 10022; (212) 355-6875. Typesetting by Grafilm, Inc., Milwaukee, WI 53210. Separations prepared by Colorcraft, Inc., Milwaukee, WI 53216. Printed by E.F. Schmidt Co., Menomonee Falls, WI 53051.

SUPERNOVAE!

by
Jeanne Hopkins

A supernova in Taurus that appeared on the fourth of July in the year 1054 left a remnant known as the Crab nebula. The Crab is an important object for astronomers today — it gives a ringside seat to a star that blew itself to bits. The Crab is still emitting gamma rays, x-rays, ultraviolet, visible light, infrared and radio energy. At its center — still supplying the nebula with energy today — is the rapidly rotating neutron star that was once the core of the supernova star. Lick Observatory photograph.


Stellar Nuclear Reactions
Gamma Ray Photon
Carbon Nucleus
Helium Nucleus
Beryllium Nucleus
The Triple-Alpha Process
Helium Nucleus
Helium Nucleus
Unstable Nuclei
Stable Nuclei
Gamma Ray Photon
Magnesium Nucleus
Neon Nucleus
Helium-Neon Fusion Reaction
Helium Nucleus
Number of Neutrons
Number of Protons
Ni
Ni
Ni
Fe Ni
Fe
Cr Mn Fe Ni
Cr
Ca Ti V Cr Fe
Ti
Ca Ti Cr
Ti
Ca Sc Ti
Ca
A K Ca
S Cl A K Ca
S Cl A
S
S P S
Si
Mg Si
Mg
Ne Na Mg
Ne
O F Ne
O
N O
C N
B C
Be B
Li
Li
He Li
H He
H

The most spectacular sight in the sky is probably a supernova: a gigantic stellar explosion that shines for a few months with the brightness of a billion suns. We must say "probably" because no supernova has been seen in our galaxy for nearly 400 years. Yet by the law of averages, at least one supernova should occur in the Milky Way every 50 years or so. A visible supernova is therefore long overdue.

Only a few stars in a million are expected to end their lives so violently, but those few include some of the brightest stars in the sky. Betelgeuse, Antares and Spica (to name just three) are expected to eventually blow up as supernovae. Those three stars have one thing in common: mass. All are many times as massive as our sun. The more massive a star, the rarer it is. For every star like our sun, there exist thousands of lighter ones, and for every thousand sun sized stars, there are only two or three that are very much heavier. Since it is the more massive stars that end their lives as supernovae (for reasons explained later), we should not be surprised at their rarity.

Since no supernovae have been observed in our galaxy since just before the invention of the telescope, astronomers have searched ancient records for accounts of them — finding only four such recorded events in the last millennium that were unquestionably supernovae. Many "guest stars" (as the Chinese called them) have appeared, but most of these are now known to have been either comets or ordinary novae.

Novae are relatively common objects; dozens appear every year in the Milky Way, although few are visible to the naked eye. An unusually bright one — the brightest in 33 years — appeared in the constellation Cygnus in 1975. For one or two nights in late August of that year, Nova Cygni was a second magnitude star.

The processes that produce novae are reasonably well understood. As far as we can tell, a nova always occurs in a close binary system composed of a red giant and a white dwarf. Some of the hot gases in the outer parts of the bloated red giant have become trapped in the gravitational field of the white dwarf. Those gases rain down on the thin, flammable hydrogen atmosphere of the dwarf, heating and compressing it until it blows up in a nuclear explosion — a series of "hydrogen bombs" that rip off the dwarf's atmosphere with such violence that, for a few days, its light is seen as a nova in Earth's night sky. Only the star's outer atmosphere, however, is affected, amounting to less than 1/1000 of its mass. The reaction is not self-sustaining, and the white dwarf soon settles down until another such event occurs and the whole cycle is repeated (see "Exploding Stars", ASTRONOMY, February 1976).

The atomic nuclei are arranged on this chart by the number of protons and the number of neutrons contained in their nuclei. Elements are built by nuclear fusion in the core of a star; the arrows show the major reactions as hydrogen becomes helium, helium becomes carbon in the Triple-Alpha Process, and the heavier elements up to iron are formed. All the reactions on this chart give off energy, but iron fusion reactions absorb energy, dooming the star to supernova.

A supernova is much more than an unusually bright, long lasting nova. It is, in fact, a completely different phenomenon. Novae occur on a star's surface; supernovae shatter or collapse the very core of a star.

Because our understanding of supernovae is dependent to such a great extent on historical records, we should briefly review these objects. What may have been the brightest in recorded history appeared on May 1, 1006 A.D., in the constellation Lupus. To observers in the northern hemisphere, it was very low above the horizon; the only extant Western eyewitness account is that of a Swiss Benedictine monk who observed it for three months. Arabic astronomers, however, meticulously recorded its appearance for several years. At maximum it was about half as bright as the full moon, and it cast a shadow.

Like all other supernova remnants, that of the Lupus supernova emits powerfully at radio wavelengths. Scientists have recently found that it is an x-ray source as well, but all efforts to identify it optically failed until last year. In early 1976, University of Toronto astronomer Sidney van den Bergh managed to record faint nebulosity on plates he took with the 158 inch (4 meter) telescope at Cerro Tololo Inter-American Observatory in Chile. These diffuse wisps of gas are all that is left of the Lupus explosion. The rest of the material has presumably dissipated into the surrounding interstellar medium.

The next recorded supernova appeared 48 years later in Taurus (the well-known Crab nebula is its remnant). Unlike the Lupus supernova, this "new star" would have been easily visible to European observers, but it remained unnoticed — or at least no European records survive. To suggest that the vault of heaven might not be constant and perfect was a heretical idea in the Middle Ages, and if some watcher of the skies did record his observations, they may have been suppressed or destroyed.

But Far Eastern observers faithfully recorded the appearance of the "guest star" in Taurus. It appeared on July 4, 1054 A.D., and was visible for 653 days. It was by far the brightest star in the sky and for 23 days it could be seen in the daytime.

Further confirmation comes, surprisingly enough, from the western hemisphere. One of the cave drawings of the Navajo Indians in Arizona shows a crescent moon with a bright star above the cusp — just where the Crab supernova would have appeared to the Navajos of that era.

If Western observers did not notice the supernova of 1054 at the time of its appearance, they have made up for it since. Though it wasn't recognized as the remnant of the Taurus supernova until the 1920s, the Crab nebula has intrigued astronomers for two centuries. It is the first object on Messier's list of annoying noncometary objects compiled in the late 18th century. The great astronomer William Herschel considered it the oddest object in the sky.

In the past decade, scientists have found that the Crab nebula is even odder than Herschel thought. It not only radiates copious amounts of energy at visual wavelengths, but is one of the strongest sources in the sky at all other wavelengths — radio, infrared, ultraviolet, x-ray, and gamma ray. And 10 years ago, a pulsar was discovered at its center.

There are two faint stars apparently close to the heart of the Crab nebula. Before the discovery of the pulsar, most contemporary astronomers thought that if a dense remnant of the supernova existed, it must be the star nearer the center. The late Dutch-American astronomer Walter Baade was one of the few who felt otherwise. Baade maintained that there was something peculiar about the other star (and any star left by a supernova would have to be peculiar in many ways). He has since been vindicated: Baade's star is now known to be the pulsar, while the other is merely a foreground star. This pulsar was the first to be optically identified with a visible star — presumably the dense neutron star remnant of the supernova. The visible star pulses at the same period (30 times per second) as the radio pulsar; similar pulses have been recorded at x-ray and gamma ray frequencies.

By the 16th century the Renaissance had arrived in Western Europe, bringing with it a rebirth of astronomy. Tycho Brahe, one of the finest naked eye observers in history, was fortunate enough to witness the next supernova in 1572. This object, which appeared in the constellation Cassiopeia, was for a few days brighter than Venus and visible in the daytime. Brahe observed it for 457 days, after which it faded into invisibility. He was so impressed that a year later he wrote a book about it: **De Stella Nova** ("On the New Star"), from which we got our word *nova.* (The word nova has turned out to be inappropriate, since a nova is not a new star but, in fact, a very old one.)

Unlike the Crab nebula, the remnant of Tycho Brahe's supernova is very faint. It wasn't until 1949 that Baade managed to take the first photograph of it with the then-new 200 inch telescope at Mount Palomar. Searches for a pulsar at its center have been unsuccessful.

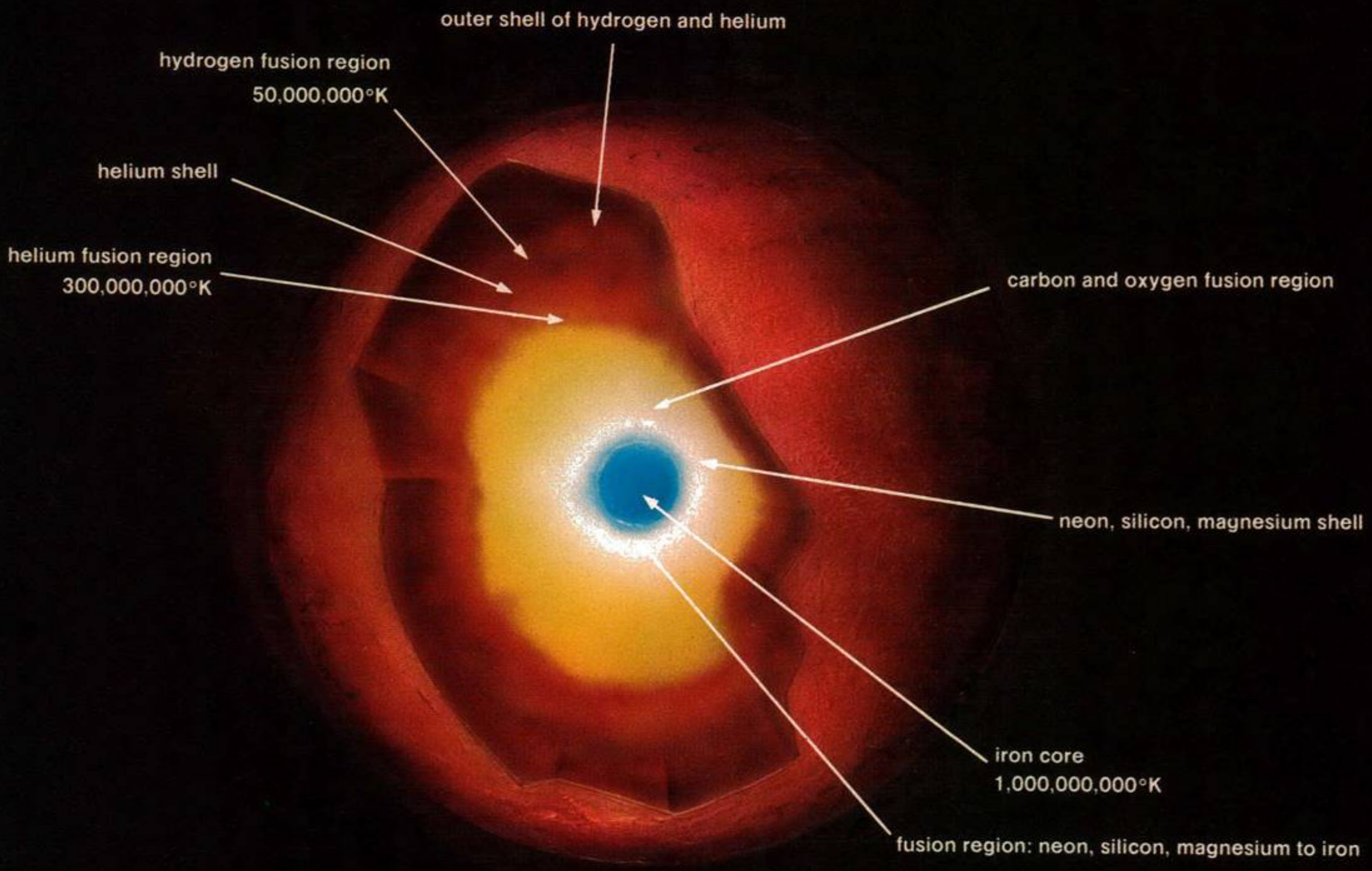
The last supernova to be observed in our galaxy appeared in the constellation Ophiuchus in 1604. This "new star", which was about twice as bright as Sirius, was carefully observed for 356 days by Tycho Brahe's assistant and successor, Johannes Kepler. It was Kepler's supernova that sparked Galileo's interest in astronomy, and Galileo's first astronomical observations were made of the star. Only five years later, after hearing about a Dutch optician's experiments with multiple lenses, Galileo constructed his first telescope, turned it toward Jupiter, and discovered the four large Jovian moons. Unfortunately, by this time the supernova was no longer visible. If it had occurred only five years later, or if it had been five light-years more distant, we might now have telescopic records — however crude — of a supernova in our galaxy.

The above four "guest stars" are the only certain supernovae that have been seen in our galaxy in the last thousand years. There are, however, at least three other interesting objects that have since appeared. The first is Cassiopeia A, the strongest radio source in the sky. Visually it is a supernova remnant, and from its present size and rate of expansion, astronomers can extrapolate back to the time it must have exploded. Presumably its light should have reached Earth about 1670, but there is no record that it was ever seen. Kepler and Galileo were no longer alive, but Newton, in his mid-20s at the time and at the peak of his intellectual powers, had already designed, constructed and used his own telescope. And John Flamsteed, who was to become England's first Astronomer Royal, was already making the observations that would later bring him fame. Certainly these two men — among others — would have noticed a "new star" if one had been visible. The most likely explanation is that the dense regions of interstellar dust that lie along the line of sight to Cassiopeia A degraded the supernova's visible light into invisible infrared radiation. Astronomers have searched for a pulsar in the vicinity of Cassiopeia A, but so far without success.

Another notable object is the peculiar variable Eta Carinae. Recorded as a fourth magnitude star by Edmund Halley in 1677, it brightened to first magnitude in 1827, and reached a maximum magnitude of -0.8 in 1843. For the next several years it was the second brightest star in the southern sky. Astronomers estimate that at its brightest, it radiated a total energy at all wavelengths (mostly in the infrared) of about 10 million times that of our sun. (Today it is only a sixth magnitude object optically, although in the infrared it is still the brightest star in the sky; recently it has started to brighten again at visual wavelengths.) The late Swiss-American astronomer Fritz Zwicky, who discovered more than 100 extragalactic supernovae (more than any other observer), maintained that Eta Carinae was a rare type of supernova. His opinion, however, is not shared by all astronomers.

The third object is S Andromedae. There is no question that this was indeed a supernova, and it was well observed. However, S Andromedae did not appear in our galaxy, but in the nucleus of M-31, the great galaxy in Andromeda. It was first seen in early August 1885, and was visible for more than seven months. Contemporary observers reported it to be between sixth and seventh magnitudes, and also reported that the whole "nebula" (as it was then

Explosion of a Star

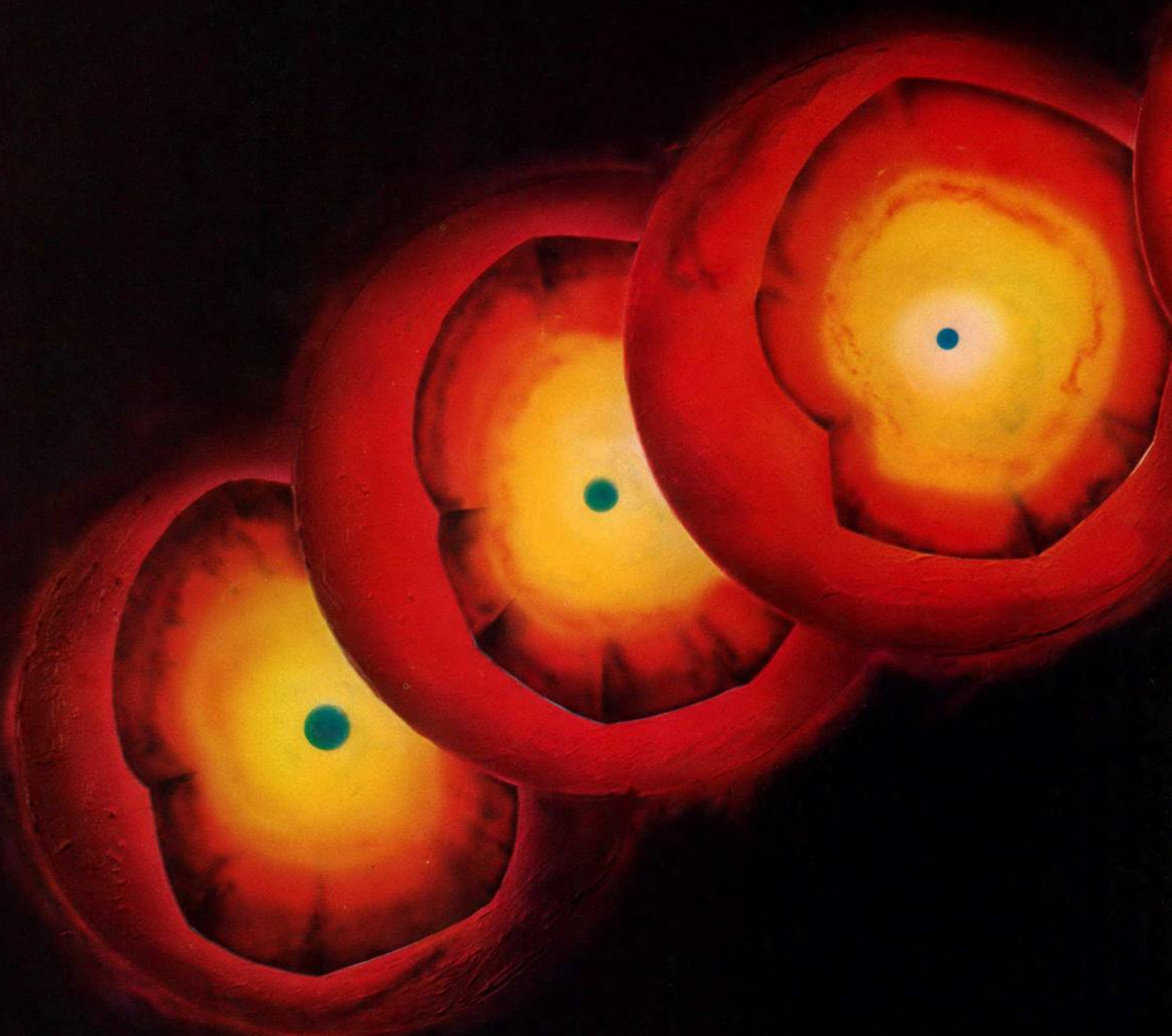

outer shell of hydrogen and helium
hydrogen fusion region
50,000,000°K
helium shell
helium fusion region
300,000,000°K
carbon and oxygen fusion region
neon, silicon, magnesium shell
iron core
1,000,000,000°K
fusion region: neon, silicon, magnesium to iron

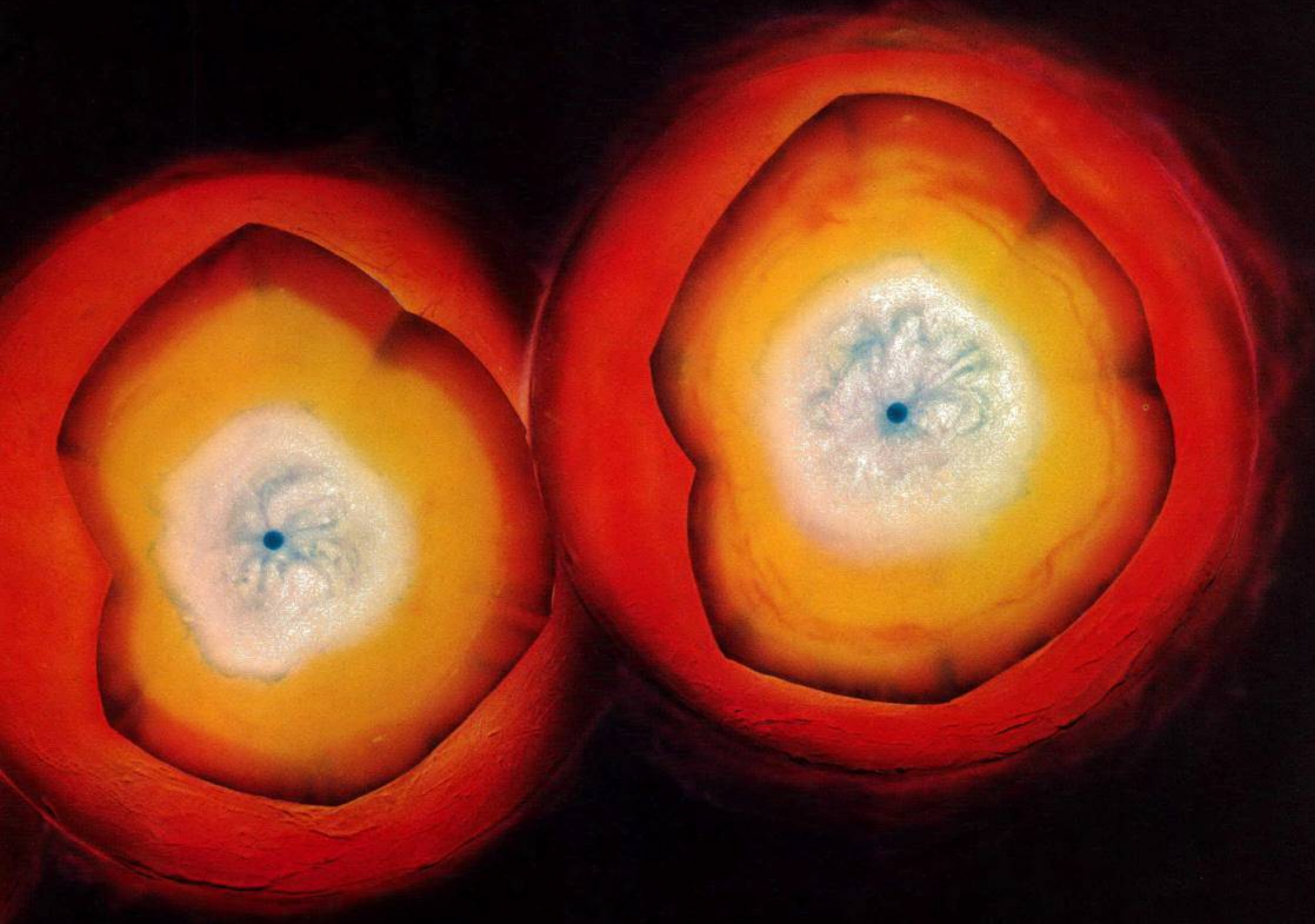
Seconds before it goes supernova, a star with 10 times the mass of the sun is layered. Each time the star has exhausted its primary fuel supply, it has contracted, its core has heated and then begun "burning" a more complex nucleus. After exhausting its hydrogen helium, it "fusions" carbon; each time the fusion products from one reaction become the fuel for the next stage.

But all the elements lighter than iron fuse to give energy. Each transition to a new fuel was stable. Ultimately the core contains nearly all iron — unstable because all further nuclear reactions absorb energy.

The nucleus of iron is the most tightly bound of all nuclei. When the iron core of a star begins to contract, there are no more energy releasing reactions to stabilize the star again. The core contracts and heats. Iron atoms begin to "fission" (break apart) into helium nuclei; under intense pressure, protons and electrons form neutrons. These reactions consume energy. The core collapses in a few thousandths of a second as runaway, energy gobbling reactions drain heat from the core.

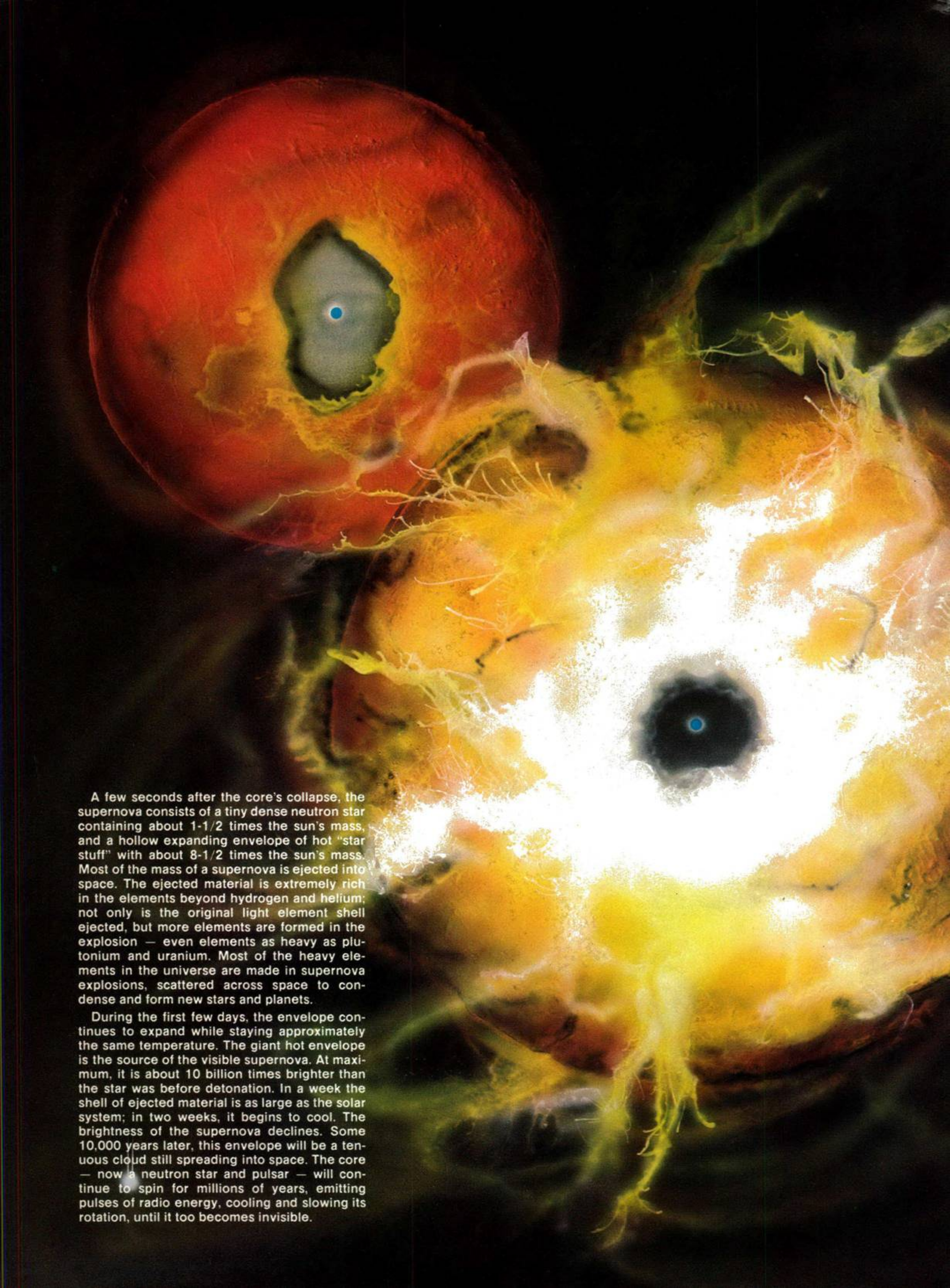
The pressure of neutron against neutron becomes great enough to balance the immense gravitational attraction of the core material. From its original size, the core collapses to become about 20 kilometers (12 miles) in diameter — a rapidly spinning rigid body composed almost entirely of neutrons and emitting an immense flood of energy.





At the beginning of the collapse phase, the entire star begins to fall inward — only a tiny bit at the surface, but quite rapidly deep inside the star. As the core collapses, it emits a flood of neutrinos (from neutron building reactions) — high energy gamma rays and x-rays — that violently heat and push the layers immediately surrounding the core outward, away from the core, at speeds as high as 10 percent of the speed of light.

Thus, the star is split. The core falls inward to become a neutron star while the outer 80 to 90 percent of the star is blasted into space. The elements in the outer layers undergo further nuclear reactions during the violent explosive phase, forming all the elements in the atomic table.



A few seconds after the core's collapse, the supernova consists of a tiny dense neutron star containing about 1-1/2 times the sun's mass, and a hollow expanding envelope of hot "star stuff" with about 8-1/2 times the sun's mass. Most of the mass of a supernova is ejected into space. The ejected material is extremely rich in the elements beyond hydrogen and helium; not only is the original light element shell ejected, but more elements are formed in the explosion — even elements as heavy as plutonium and uranium. Most of the heavy elements in the universe are made in supernova explosions, scattered across space to condense and form new stars and planets.

During the first few days, the envelope continues to expand while staying approximately the same temperature. The giant hot envelope is the source of the visible supernova. At maximum, it is about 10 billion times brighter than the star was before detonation. In a week the shell of ejected material is as large as the solar system; in two weeks, it begins to cool. The brightness of the supernova declines. Some 10,000 years later, this envelope will be a tenuous cloud still spreading into space. The core — now a neutron star and pulsar — will continue to spin for millions of years, emitting pulses of radio energy, cooling and slowing its rotation, until it too becomes invisible.

called) brightened by about a magnitude. Though it aroused a great deal of interest among astronomers, it seemed to be only an unusually bright nova, because at that time M-31 was believed to be part of our own Milky Way and located only a few thousand light-years away.

Ironically, when the idea was advanced a few years later that the Andromeda nebula was not part of the Milky Way but was a separate "island universe" at least a million light-years distant, S Andromedae was cited as "proof" against the theory. Opponents of the island universe hypothesis argued that if the Andromeda nebula were a separate system of stars so far away, then the S Andromedae "nova" would have had to have the intrinsic luminosity of billions of suns — an idea that was considered preposterous.

When it was finally established in the 1920s that the great nebula in Andromeda really is a separate galaxy more than a million light-years away (or, as is now believed, more than two million light-years away), astronomers realized that S Andromedae could not possibly have appeared so bright to Earth based observers if it had been a mere nova. In 1933, Baade and Zwicky proposed that S Andromedae and similar objects be called *supernovae*.

What makes a star go supernova? The physics of supernovae are not well understood, at least partly because of the dearth of observations. The only modern data astronomers can obtain are from supernovae in other galaxies millions of light-years distant. Scientists cannot see or photograph a star either before or after it goes through the supernova phase, so they cannot tell what kind of star it originally was, or what it has become since the flare-up.

Undaunted by the lack of detailed observations to test their models, theorists have formulated a scenario for supernovae that fits the scanty evidence they have — at least as far as the main features are concerned. To understand their theories, we must know something about stellar life cycles.

In a star there is a constant tug of war between two opposing forces. The star's own gravity tends to pull its material inward; but on the other hand, the energy generated by nuclear reactions in its core pushes matter outward. Ordinarily these two forces are in a very stable balance. In all stars, however, the supply of nuclear fuel runs out sooner or later, whereas gravity never gives up.

Let's take the star we know best — our own sun. Like all other main sequence stars, the sun is now fusing hydrogen into helium in its core. Every second, about 655 million tons of hydrogen are being transmuted into 650 million tons of helium. The 5,000,000 ton difference represents the mass converted into energy that makes the sun shine.

In spite of losing 5,000,000 tons of mass every second, the sun still has enough hydrogen fuel to keep shining for another five billion years. When the hydrogen is finally exhausted, the inexorable pull of gravity will contract the sun's core, heating it until the temperature becomes high enough for the helium "ash" to take fire and fuse into carbon.

The sun can go only this far in nuclear fusion. When the helium in the solar core has been "burned" into carbon, gravity will again take over, pulling the core inward until it is about the size of Earth and has a density of several tons per cubic inch. At that density the atoms begin to touch, the electron orbits encroach on each other, and the pressure of the constantly moving electrons provides the force to counterbalance gravity and keep the sun from contracting further. When a star reaches this first plateau, it is called a white dwarf. At one time white dwarfdom was believed to be the ultimate fate of all stars. It is still believed to be the fate of more than 99.9 percent of them. The remaining fraction of one percent is what interests us here.

In the summer of 1929, an 18 year old graduate of Madras University in India booked passage on a ship for England to enroll in graduate school at Cambridge University. To while away the hours on the long, hot trip, he started some intricate mathematical calculations, applying Einstein's equations to the theory of white dwarfs. Three months later, when he arrived in England, the calculations were finished — with the astonishing result that no white dwarf with more than 1.4 times the mass of the sun could exist! If it were more massive than this, the weight of the overlying layers would be so great that not even the pressure of the constantly moving electrons could support it.

This limit of 1.4 solar masses is now called *Chandrasekhar's limit*, after the young Indian astrophysicist who calculated it. All of a star's evolution beyond the main sequence depends on whether the mass of its core is above or below Chandrasekhar's limit. If it is below, it will become a stable white dwarf. If it is not below — or if it cannot somehow shed enough mass to get below — then, as Chandrasekhar said in his original paper, "we are left speculating on other possibilities."

Before we go into the "other possibilities", let's discuss how a star that is initially above Chandrasekhar's limit can shed enough mass to get below — because we know that it *is* possible. For instance, there is a white dwarf in the Pleiades. The Pleiades are a cluster of extremely young stars; they were all born roughly 20 million years ago — about the time the first apes appeared on Earth. Observations show that all Pleiades having less than six times the mass of the sun are still on the main sequence, so this white dwarf must have originally been more massive than that. But it cannot now be more than 1.4 times the mass of the sun, or it could not be a white dwarf. So it must have been able to shed at least 4.5 solar masses in some way. How? One way might be the following: The sun has a retinue of planets, in which resides most of the angular momentum of the solar system. As a result, the sun rotates quite slowly — about one mile per second at its equator. If by some means all the planets were to spiral into the sun, its rotation rate would be increased to about 60 miles per second. At that rate, when the sun became a red giant, its tenuous outer layers would probably spin off to form a planetary nebula like the well-known Dumbbell or Ring nebulae. If a star having as much as six or seven times the sun's mass could rid itself of enough material in this way to get below Chandrasekhar's limit, it could settle down into serene old age as a white dwarf.

But suppose it can't? Then, as Chandrasekhar said, we are left speculating on other possibilities. Astronomers know a little more about those other possibilities now than they did nearly 50 years ago. Calculations have shown that a star with more than eight times the mass of our sun will be unable to shed enough mass to get below the Chandrasekhar limit. When such a star's helium is exhausted, gravity can bring the carbon core to a temperature and density high enough to "burn" the carbon successively into neon, oxygen, silicon and finally iron. The nuclear fires will then go out, and this time the pressure of the electrons will be unable to halt the inward pull of the star's gravity. The electrons will be forced together until they merge with the protons to become neutrons. This removal of the supporting electrons accelerates the collapse. Finally, when the neutron core has a diameter of perhaps 10 miles and a density of at least 10 million tons per cubic inch. The pressure of the constantly moving neutrons keeps gravity from collapsing the star still further. At this point the star is a neutron star — the second plateau.

If the star's collapse is violent enough, however, even neutron pressure cannot save it. The collapse goes right through the second plateau, and the star becomes a black hole.

In either case, the collapse of the core forces the ejection — at supersonic velocities — of the tenuous, loosely held outer layers of the star. As the outermost shell expands, it sweeps up all the material in its path. Depending on the amount of material it picks up, the shell is slowed down, perhaps even to the point where it falls back toward the star. Meanwhile, the next outermost shell is ejected, also at supersonic speeds. It expands unchecked into the region swept clean by the previous shell, catches up with and overtakes the outermost shell. The result is a tremendous shock wave — a sonic boom strong enough to shatter a million Earths. This is the visible supernova. At the interface of the shock waves thus produced, for a few seconds the conditions are so extreme that all the elements in the periodic table are synthesized, including the transuranic elements (those heavier that uranium). Without supernovae, therefore, no life could exist, for there would be almost no heavier elements. Most of the atoms in our bodies heavier than carbon are bits of stardust from supernovae.

It should be emphasized that this scenario is something of an act of faith among astronomers. Theoretical calculations show that the big bang could not have produced any element heavier than helium. And ordinary stable stars cannot produce elements much heavier than carbon. Yet elements heavier than carbon exist. Where did they come from? Experiments with large accelerators have given physicists an idea of the temperatures and densities required to produce these heavy elements. The only place in nature where such extreme conditions are believed to exist is in supernovae.

If supernovae have occurred in our galaxy at the expected rate of one every 50 years, then about two percent of the mass of the galaxy has been processed through supernovae. This agrees with the observed cosmic abundance of "heavy" elements. Further evidence that astronomers are on the right track comes from the transuranic elements, unknown on Earth before man learned to manufacture them artificially. A certain spectral line, found in the spectra of supernovae in other galaxies, seems to come and go with a period of about 55 days. The line is at the place in the spectrum where (theoretically) there should be a line of the transuranic element californium, which has a *halflife* of 55 days. (An element's halflife is the time needed for half the nuclei in a sample of the element to undergo radioactive decay.)

More convincing and better established is the presence of a rare isotope of xenon in meteorites. The xenon isotope is produced only as the decay product of plutonium-244, which has a halflife of 82 million years and is therefore extinct in the solar system. But the presence of the decay product in meteorites is convincing evidence that plutonium existed in the original material out of which the solar system formed. And the plutonium must have come into being, somewhere, not many times 82 million years previously.

What remains of a star after its supernova phase? We have already mentioned neutron stars. Until 1967, such stars were usually regarded as figments of the theorist's imagination — but then pulsars were discovered. It is now generally accepted that pulsars are rotating neutron stars, the dense core left from supernova explosions. More than 100 are now known, and perhaps many hundreds more exist in our galaxy. Pulsars have relatively short lifetimes (a few million years) before their energy sources are exhausted. (The neutron star remains, of course, but since it no longer emits pulses it would probably be undetectable.)

Supernova remnants also exist. These are large expanding shells of gas that give visual evidence of an earlier explosion at the center. Again, more than 100 are known in our galaxy. Supernova remnants have even shorter lifetimes than pulsars — less than one million years. But there is almost no overlap between pulsars and supernova remnants; very few pulsars are surrounded by supernova remnants, and very few supernova remnants are known to have pulsars at their centers. Why? One theory is that when the core collapses to form a neutron star, it is shot out of its orbit at a very high velocity and becomes a "runaway star". Over the centuries, it would have reached a spot in the sky far from its original position.

At least one black hole has probably been discovered — against overwhelming odds. To search the sky for something that, by definition, cannot be seen would ordinarily be an exercise in futility. Nevertheless, Cygnus X-1 (so-called because it was the first x-ray source to be discovered in the constellation Cygnus) is now generally believed to be a black hole. It is in a close binary system, and from its gravitational effect on the visible member, astronomers have been able to calculate its mass and radius even though the object itself is invisible. It is too massive and too small to be either a white dwarf or a neutron star. So, in the words of Sherlock Holmes: "When you have eliminated the impossible, what remains, however improbable, must be the truth."

We've said that a supernova was long overdue. What will happen when the next one appears — perhaps tomorrow, perhaps a century hence? That depends to a great extent on how near it is to us. The historical supernovae discussed here were thousands of light-years away, and had little if any effect on Earth, as far as we know. But if one occurred within about 100 light-years of the sun, the increase in x-ray and gamma radiation would undoubtedly destroy the ozone layer in Earth's atmosphere, which protects the planet's surface from the harmful ultraviolet radiation from the sun. The DNA molecule is especially susceptible to ultraviolet radiation. Destruction of the ozone layer would, at the very least, result in a large increase in the mutation rate — and could conceivably destroy a high proportion of existing life.

Astronomers calculate that supernovae occur within 100 light-years of the sun every 60 million years or so. Paleontological records show that, since the appearance of reptiles on Earth about 300 million years ago, different animal species have periodically become extinct; about every 60 million years some species has suddenly disappeared. This coincides with the expected rate of a "nearby" supernova every 60 million years. The most spectacular example of such a disaster is the disappearance of the dinosaurs at the end of the Mesozoic era.

Of course, the chances that the next supernova will be that close to us are very slim; the odds are overwhelming that it will be a safe distance away. And when that spectacular "new star" does appear in the sky, all the resources of modern technology will be turned to it, and astronomers will finally have a chance to test their theories close at hand.

ASTRONOMERS IN SPACE

PART 1

by

James E. Oberg

Astronomers have traveled great distances in the pursuit of their science. Venturesome and hardy, they have crossed thousands of miles of oceans, deserts and jungles chasing eclipses, occultations or transits. Seeking better "seeing", astronomers have climbed hundreds of mountains, built observatories at high altitudes, and endured cold, thin air and isolation. Just as it was at its birth thousands of years ago, astronomy today can be outdoor work, a strenuous science, and a physically demanding activity.

Within a few years, some astronomers will be making scientific expeditions to more distant destinations, seeking better "seeing" and for special phenomena unobservable from ordinary locations. Having sent their instruments and advice into space, astronomers themselves will soon follow.

On NASA Space Shuttle missions of the 1980s, astronomical payloads will be common. Astronomers will be sent into orbit many times a year to control space observatories. Their activities will revolutionize even the rapidly changing field of space astronomy.

Orbital observatories will be of several different kinds, and most astronomers involved in the program will not actually go into space (nor will they want to, when they discover all the requirements). The *free-flyer* observation satellites will be automatic telescopes controlled from the ground. Only occasionally will astronaut crews visit them for purposes of check-out, repair, resupply, film retrieval, and changeout of instruments. Other free-flier satellites will be expendable, built by a single university or even a single astronomer, and delivered into orbit as "space available" hitchhikers.

The other type of space observatories will be the Space Shuttle instrument pallets, carried in the payload bay of the orbiter spaceplane. These instruments will remain attached to the orbiter for the entire mission and will return to Earth with it. Crewmen on board the vehicle, and other specialists back on Earth, will together run the experimental programs.

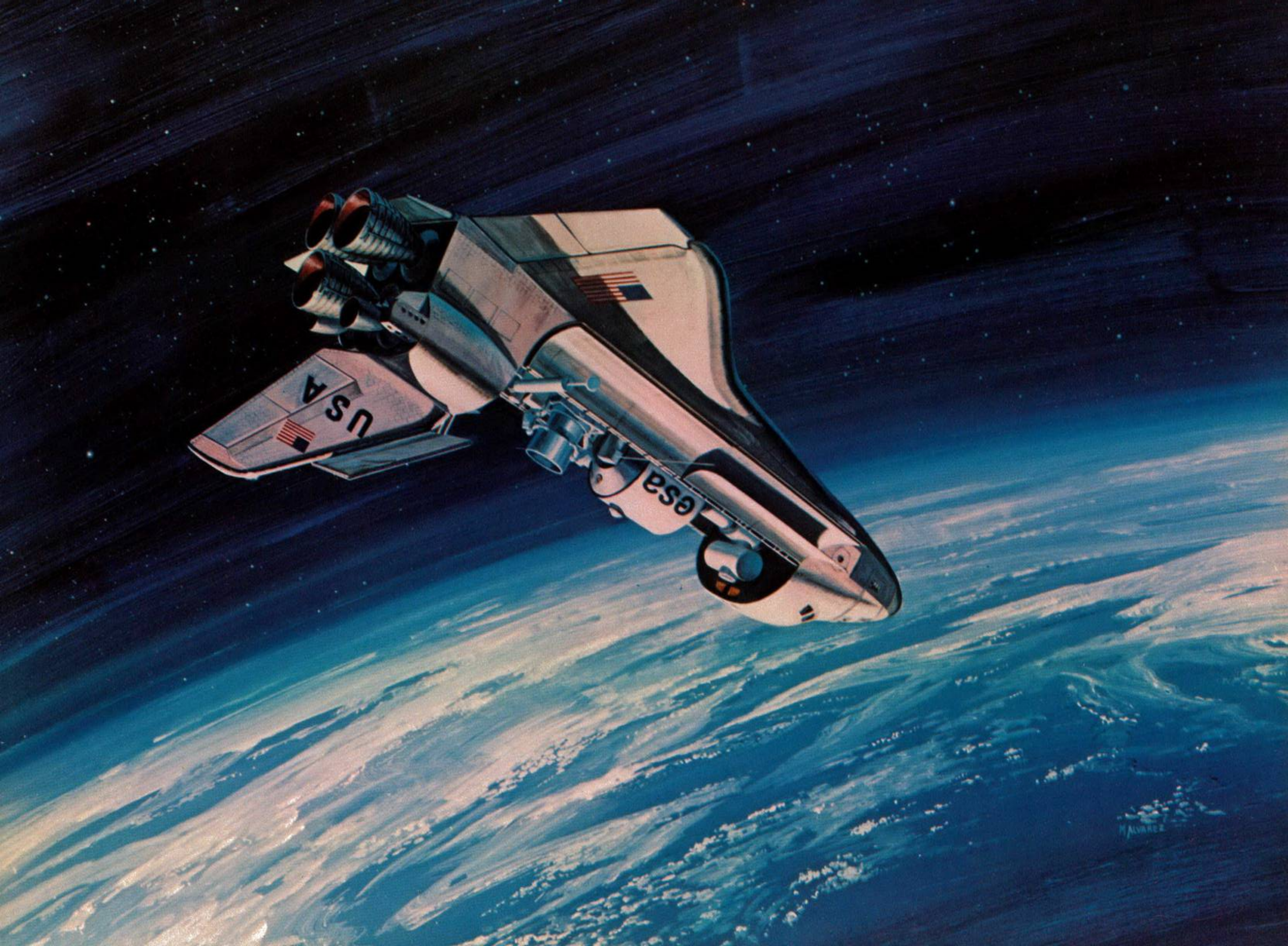
Astronomical probes of the free-flier type range from small Explorer satellites (like the Gamma Ray Explorer) to the large remote controlled giants like the Space Telescope, which will send all the data back to Earth via telemetry.

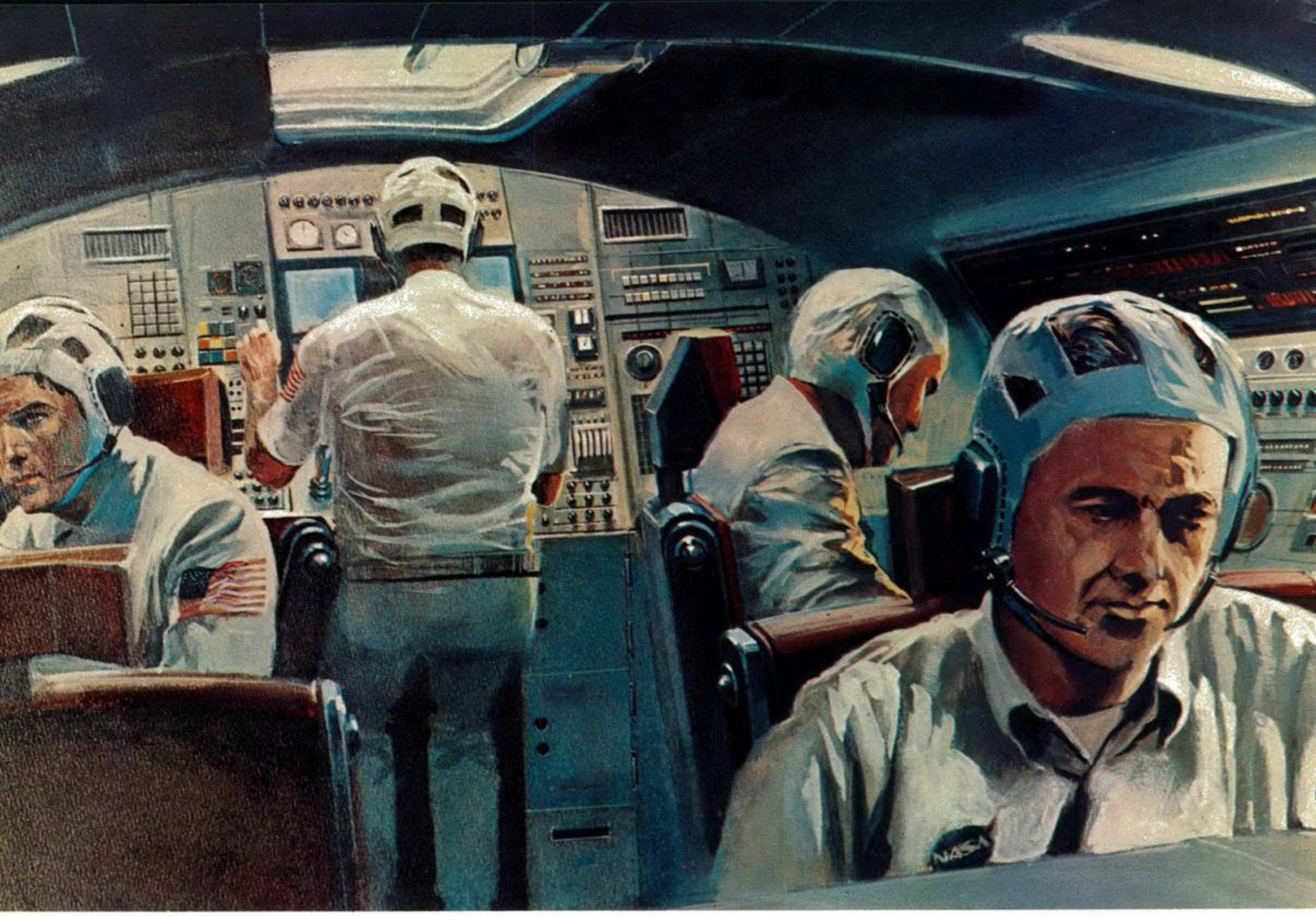
Astronomical probes of the second type include special shuttle-carried units such as the Shuttle Ultraviolet-Optical Telescope (SUOT), two types of high energy astrophysics payload combinations, a solar physics observatory, and other large telescopes operating in the visible ultraviolet and infrared spectra.

Space astronomers will also form two different groups from two distinct sources. Perhaps a half dozen full time astronauts will be professional astronomers — civilian scientist-astronauts, with Ph.Ds and many years of experience with the equipment and theory of spaceborn astronomy. The second group (which will comprise the majority) will consist of "temporary" astronauts — astronomers from the "outside" world who fly into space to conduct specific experiments for which they are uniquely qualified. They will train part time, and then take leaves of absence or sabbaticals from their regular university, laboratory or industrial professions.

The full time astronomer-astronauts will be

A frequent passenger aboard Space Shuttle missions will be the European Space Agency's Spacelab module. The round pressurized module contains scientists and electronic controls, while the instruments operate in high vacuum on an external pallet. The orbiter can be flown facing Earth for resource and geophysics missions, or turned and flown facing toward space for missions dealing with astronomical objects. NASA artwork.


USA
esa
M. ALVAREZ



Inside the cockpit of the Space Shuttle orbiter are provisions for four astronauts. The crew member facing away from the viewer is the mission specialist — an astronomer-astronaut who carries the responsibility for the space research program to be carried out on this mission. Shown at a console for remotely operating an experiment in the payload bay, the mission specialist may operate many other experiments besides his/her own. NASA artwork

part of a cadre of NASA *mission specialists:* astronauts who will not pilot the Space Shuttle, but who will be in charge of the research program once in space. The mission specialist will also be the prime crewman for any extravehicular activity (EVA) required during the mission. He or she will essentially be the *science officer* of the space expedition.

Two astronomers have already been in space training for almost 10 years. When Karl Henize and Robert Parker were picked as scientist-astronauts in 1967, NASA had a series of advanced Apollo lunar missions and Skylab space stations scheduled. The budget cuts, after Apollo, eliminated these extra astronomer flight opportunities, so the astronomer-astronauts have spent their time supporting the science activities of Apollo and Skylab. These two men are now engaged in advanced planning and training for the Space Shuttle astronomy programs, and they will probably be joined in mid-1978 by several new astronomer-astronaut candidates.

Payload specialists, intimately involved with the development of astronomical instruments or observing programs, will undergo several months of intensive general space training while concentrating on the development of hardware and plans for the particular space mission. After a few weeks in space, these temporary astronauts will return to their homes to analyze the experimental data. They might make a flight once a year, once in a decade, or perhaps only once in their lifetime.

During the mid-1980s — only a decade away — NASA plans call for 40 or more shuttle missions annually. Many of these will be satellite launchings, repair or retrieval missions, and other flights on which no scientists will be required. Many others (perhaps as many as 40 percent) will carry Spacelab pressurized laboratory units, instrument pallets, or a combination of the two. There will be a full crew complement of two pilots and five scientists, most of whom will be payload specialists.

To support this ambitious but realistic program, NASA will probably require a corps of astronauts larger than the two dozen spacemen now on active duty. Forty flights for two prime and two backup pilots will generate 160 flight assignments each year. Since a flight will require two months of preparation for the trained pilots, a group of 25 pilots will be the minimum number involved. As many are removed from the duty roster for advanced or refresher training, vacation, or for other duties, 30 or more will be needed. The longer lead time for scientific planning will probably require a group of 20 to 30 mission specialists who may make one or two flights every year. These men and women will work closely with the payload specialists.

Visiting scientists and technicians will fill the extra 50 or more space seats every year. Over the years, hundreds of different scientists will thus have the chance to fly into space. A large portion of this group will consist of astronomers and astrophysicists.

As far as the regular astronaut group is concerned, maintaining a corps of 60 or so full time spacemen will probably require recruitment of a dozen new astronauts every two years, as older astronauts retire or transfer to nonflight positions in the space program. During that same period, 100 payload specialists will be selected, trained and launched. The payload specialist program is clearly the way that most astronomers will get into space 10 years from now.

The road into space for an astronomer in the mid-1980s will closely resemble the following outline. Plans, payloads and patterns of training and operations are, of course, speculative. The speculation, however, is firmly based upon standard NASA operational programs and experience.

Numerous astronomy payloads will be flying on the Space Shuttle. The Space Telescope will already be in orbit, being remote controlled from a ground center at the Goddard Space Flight Center outside of Washington, D.C. Pressurized laboratories will be carried into space for expeditions lasting up to a month or (toward the end of the 1980s) longer. Instruments will be launched to study the heavens, Earth, and the very structure of matter. Space factories will examine and exploit the unique characteristics of orbital flight; space power plants will be starting a test program of electrical transmission which could lead to the opening of limitless power resources from space.

Astronomers, in turn, will have a number of instruments making regular orbital flights. These will include the previously mentioned SUOT, a solar physics observatory, one or two different configurations of high energy astrophysics observatories, and a 60 inch (1.5 meter) infrared telescope.

NASA will issue periodic "Announcements of Opportunities" for payloads and for payload utilization, which will be distributed throughout the scientific community. "Announcements of Instrument Opportunities" will also be circulated, advertising available space on specific missions for specialized observation programs.

Imagine that you're an astronomer at a private university. While reading literature on ultraviolet sky surveys being made by shuttle based telescopes, you have an idea for a new instrument and a radical new observing program. You've already tested the instrument on short, high altitude balloon flights, and it has returned impressive results. A former classmate of yours has already been selected for a Space Shuttle expedition, and so you also decide to apply.

You inform NASA of your intention to submit a proposal, and subsequently NASA sends information and requirements to you. Perhaps working with three colleagues or graduate students, you finally complete the paperwork, describing in detail your instrument, its potentials, problems, proven performance, and the contributions it could make to astronomy. Then you drop the package off at the post office (registered mail, of course) and try to convince yourself that you never wanted to go into space anyway.

Depending on the proposals at hand (some recently submitted and some on file), together with knowledge of other capabilities not registered but still available at numerous laboratories, a NASA science board works out a tentative combination of plans for a flight. Advised by the National Science Foundation and other national scientific groups, the NASA committee contacts the selected experimenters and asks for still more information.

The first step in preliminary flight planning is to inspect the telescope you will use. It's already slated for an orbital flight within a few weeks, with different experimenters, but you visit the maintenance facility and talk to the instrument designers and engineers. It's a beauty.

You might be working with a Deep Sky Ultraviolet Survey Telescope. It weighs 8,800 pounds (4,000 kilograms), and displaces about 18 feet (6 meters) of the shuttle's long payload bay. The survey instrument is an all-reflecting Schmidt f/3 system with a 0.75 meter aperture and a five-degree-square field of view. Both film and electronographic cameras can be used to obtain imagery of 23rd magnitude stars with resolution of one second of arc.

The general objectives of this particular instrument are direct imaging and spectral surveys in the ultraviolet of comparable quality to available ground based surveys in the visible bands. A search for anomalous objects is also being made for further study by a one meter ultraviolet scope and by the Space Telescope.

The imagery and spectral ultraviolet surveys provide invaluable data on ultraviolet brightness, temperature, luminosity and morphology of innumerable types of celestial objects. When the survey is completed, it will be able to serve as a major source of statistical data and as an ultraviolet identification chart, similar to the role of the 48 inch (1.22 meter) Palomar Observatory Sky Survey (POSS) in the visible.

Your flight is still more than a year away, but because of the importance of your experiment, the NASA planning board has selected your proposal as one of four experiments which will have an on-board operator. One of you will go into space along with your instrument!

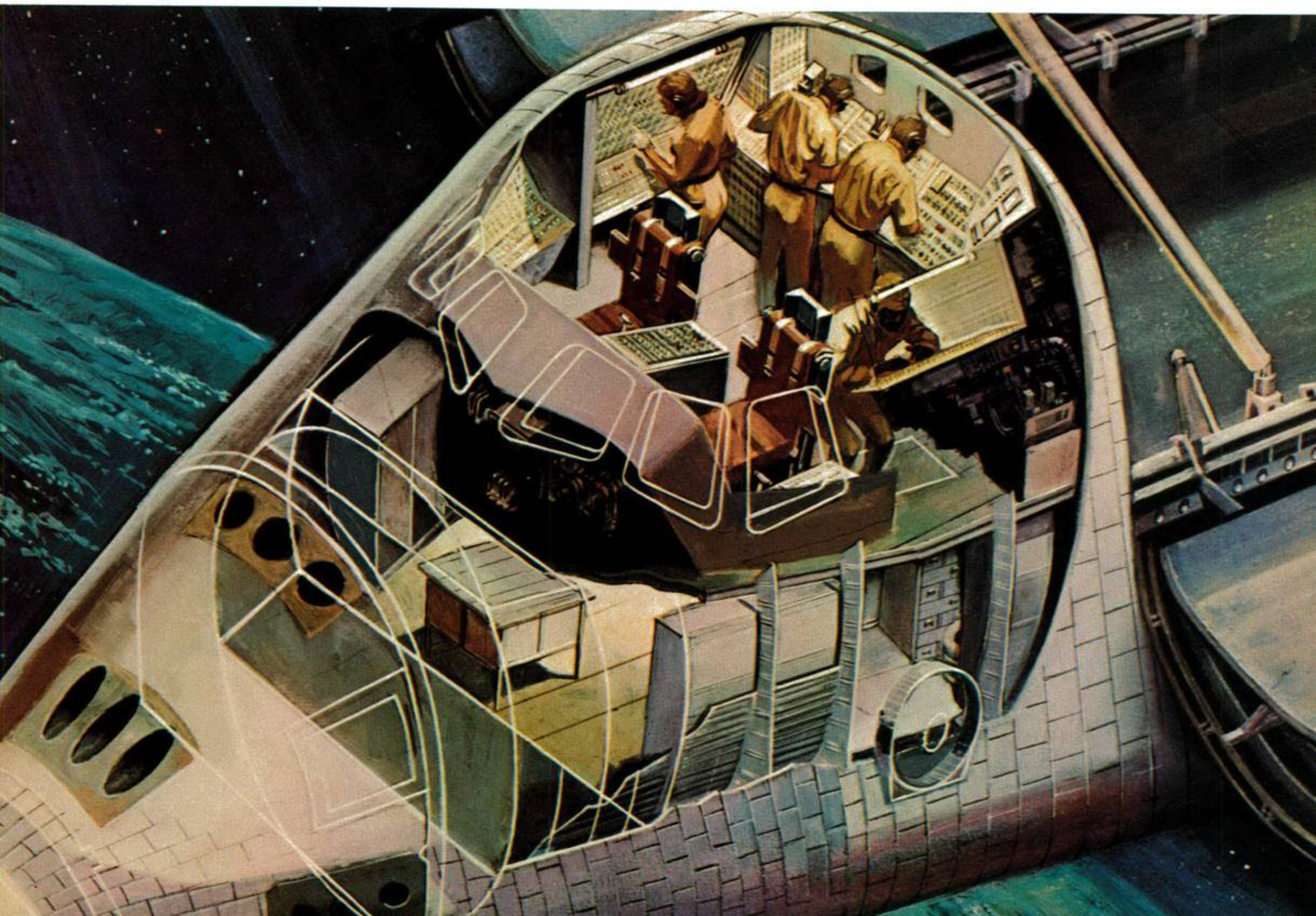
The strict flight physical exams required for the pilot astronauts are irrelevant to your qualifications, although basic health and physical well-being are still required. If your height is between 5 feet and 6 feet 4 inches, and you're in moderately good shape — with no special medications required and no physical defects — you are ready for the next step. Age and sex are not important. Your visit to a nearby Public Health Service hospital or an Air Force Base Dispensary will give the NASA planners all the medical data they need on you and your three associates. One of your associates may receive the disappointing news that certain space emergencies could be very hazardous to his health because of a childhood ear infection, and he does not pass. But you're approved — fit for space flight — though you haven't run a mile in five years!

Now documents begin to pile up on your desk. You'll study the basic Space Shuttle operations manuals, the Shuttle Users' Guide, and the hardware/software interfaces available to your instrument. Long hours on the telephone with experiment systems engineers at NASA's Houston Space Center make you start asking new questions about your instrument and your experimental program. Meanwhile, the actual flight hardware is being assembled at a university laboratory.

About 10 months before the flight, you (and your associates) will fly to Houston to meet with your mission coordinator. He is the mission specialist astronaut who will be the science officer of your flight. He is an astronomer, but has been with NASA for six years and has already been into space four times. He'll help you plan your actual inflight operations observing schedule.

As flight plans, instrument design, and your background reading continue, future payload specialist astronauts (as you have begun to think of yourself) begin commuting twice a month to Houston. On each trip, you may have as much as 200 pages to study before the next morning's training session.

Everything about living must be relearned for space. Where and how do you sleep? Where do you stow your logbooks and experimental schedule sheets? How do you control the spacecraft computers, relay data to the ground, and monitor the health and happiness of your equipment? What



The upper deck of the Space Shuttle accommodates four working crew members; the lower living quarters will accommodate up to six crew members sleeping, eating, resting, or planning the continuing mission strategy. You can see storage lockers, sanitary facilities, and the eating table on the lower level. At the left of the scene, the shuttle cargo bay doors are open, indicating that experiments are in progress. The cargo bay is closed for takeoff and re-entry. NASA artwork.

about personal hygiene and exercise? How about preparing food, eating and cleaning up? All these operations — so ordinary on Earth — require weeks of training and practice before they can be carried out in space.

Once you've mastered the basics of normal life in space, you must train for the possible abnormal events. Unlike the Apollo astronauts, you won't land in the ocean, and probably not in a remote desert. However, you must learn procedures for fast emergency escapes on the launch pad or following landing. You must practice folding up very small into the "rescue balloons", in which spacesuited pilot astronauts can pass across open space into another Space Shuttle if the vehicle you are in becomes crippled. You must learn procedures for fire and depressurization drills, communications protocol and alternative procedures. In a true emergency, you must learn to stay out of the way of the professional astronauts.

All this time, you still must hold your job at the university, teach classes, advise several doctoral candidates, attend PTA meetings, and try to live an "ordinary" life. On top of this you've got a training schedule and the all-important development and testing of your particular science instrument for the mission, now only a few months away.

It is now time for a leave of absence to pursue your research. You and your colleagues will probably take a four month sabbatical which may include a trip into outer space.

For months you've been working on yet additional space duty. Since the seven member crew will operate in two shifts, at one point you will be one of only two scientists awake. There are other instruments and experiments on the flight, and you must handle those of your sleeping colleagues as well as lesser experiments which did not justify the presence of the principle investigator on the flight. You discover that *most of your work time in orbit will not be directly connected with your own program,* and that you must quickly relearn additional specialties of stellar and solar astronomy, synoptic terrain photography, medical measurement techniques, and other tasks.

A major problem on space missions has always been crew health (especially regarding "spacesickness"). During Skylab, many members felt queasy for several days early in the flight. Space doctors were frustrated: They found no correlation between preflight training, vertigo susceptibility, seasickness and other factors, and the actual onset of nausea in space. Since the early science missions with payload specialists were only six or seven days long, it was impossible to tolerate having half the crew unfit for duty for half the flight. So a special series of medical tests were made, and new procedures — both new activity schedules and new drugs — were implemented. In accordance with further testing, your mission carries a 585 pound (261 kilogram) Life Sciences Laboratory stashed in the middeck next to the bunks. The mission specialist astronaut has prime responsibility for it, but you have been assigned second shift responsibility.

The equipment is designed to help understand the mechanisms of human response to spaceflight. The experiment's purpose is to collect high fidelity, high quality data on the new spaceflight participants (you, the payload specialist, and your associates) in order to substantiate and improve the original medical selection criteria for shuttle passengers and crews, and to develop more efficient defenses against spacesickness. You thought you were an astronomer; now you are a part time medic, too.

A major instrument on the flight is a one meter, diffraction limited ultraviolet optical telescope, weighing about 4,000 pounds (2,000 kilograms). Two other astronomers are primarily responsible for operation of its experiments, but you must study its operation in order to assist and to periodically relieve them during the 12 hour long observation periods.

According to the NASA specifications, the telescope is a Ritchey-Chretien f/16 system using a modified Cassegrain, operating in the 0.09 to 0.70 micrometer wavelength region (900 to 7,000 Angstrom), with a field of view of 1/2 degree. A secondary mirror, in conjunction with guide star trackers, will provide image motion compensation and automatic tracking to within 0.03 seconds of arc when the telescope axis is pointed to within 0.017 degrees of the target by the orbiter, under the guidance of one of the pilots.

Its purpose is to perform survey work among faint stars in galaxies in support of the 94 inch (2.4 meter) Space Telescope, and to perform observations that are inappropriate for the ST. Synoptic observations of planets and comets, astrometry, ultraviolet and optical photometry of clusters, stellar statistics of Bok globules, stellar composition and structures of nearby galaxies, and high resolution ultraviolet spectroscopy are all included in the large — but flexible — observing program. (You'll have copies on board, so you won't have to memorize it!)

Hence, this telescope allows better utilization of the ST satellite for faint objects, by observing relatively bright objects. It also allows short lead time for the use of new instrumentation (one of the payload specialists joined the flight crew only six months before launch), and for the observation of opportune targets (you'll be continuously updating your observation plan based on events like comet sightings or an unusual Martian duststorm).

The individual instruments which use the telescope include a far ultraviolet spectrometer, a polarization photometer, and a high resolution imager. Operation plans call for slewing the "configuration" to the object direction (this will be done by the pilot astronaut, and will take six minutes), switching on the instrument (six minutes, by the principal investigator), aligning and adjusting the telescope (six minutes, with your help), calibration (six minutes), locking onto guide stars (three minutes), adjusting to desired field of view (three minutes), and up to 52 minutes for observation, adjustment, and recording of data. You then have seven minutes to evaluate the data and advance the film (12 pounds of 40mm film and 15 pounds of 80mm film will be loaded in the cameras the day before launch) before the next orbit begins and a new object direction is selected. Between times you can grab a sandwich, check the manuals because of an overheated battery, respond to a ground request for a schedule change the following day, etc.

Actual flight operations are simulated at the space center in Houston, where two or three months before the flight you will begin to live nearly full time. Engineers in NASA's Johnson Space Center Building #5 have constructed mockups to run you through many operations, procedures and equipment familiarization. The time finally comes when you can handle the equipment expertly.

About two months before launch, you meet your crewmates. Pilot astronauts fly three missions per year and serve on three backup flights, leaving them two months per mission. The mission specialist astronaut and his backup astronaut have been working with you for almost a year now. The seven member crew goes through launch and entry/landing simulations together, and then begins three day-long, on-orbit simulations together. Vigorous joint social activities — including picnics and working field trips to scientific laboratories — are clearly designed to give each crew member a better idea of the capabilities and idiosyncracies of his or her associates.

Since shuttle flights have been on a routine basis for several years, you have known your launch date for at least nine months. Thirty days before launch, you all move into the space hotel at the Kennedy Space Center at Cape Canaveral, and begin reviews of all procedures and instrument programs. As a principal investigator, you're deeply involved with the final decisions on the observation programs, as the mission specialist keeps discovering conflicts between pointing and scheduling requirements for the different programs. Your instrument does not own the mission, you discover, and the final flight plan is a compromise that still provides a complete observation program.

As scheduled, you will be on duty for twelve hours, will sleep eight hours, and will have four hours for meals, hygiene (unlike the spacious Skylab, you will not have a shower), and a rigorous exercise program to maintain your body's strength in zero gravity. Importantly, you'll have two to four hours each day to study the results of the day's activities, plan the next day's program, talk with the support scientists back on Earth, and try to figure out why things are not behaving quite as you expected (they never do!). To that, add two hours of extra scientific duties, and you've got a *thirty hour day!* Since that obviously can't work, you'll have to double up your activities, carrying out a few extra experiments during lulls in the duty day, thinking about the day's results while pedaling on the bicycle ergometer, or eating a cold lunch in front of the instrument panel. The schedule (and your mental health, alertness and overall efficiency) requires at least a half day off every week, during which you can take "tourist photos" of Earth out the front window of the orbiter, listen to music, or play a relaxing game of chess with another scientist's auxiliary computer.

The commander, pilot, and mission specialist astronauts are all designated either prime or backup for this flight. During the last month before launch, the mission specialist meets with all of the trainee payload specialist astronauts, and helps each principal investigator select the actual prime and backup individuals. While the prime crewman will actually fly into space, the backup scientist will — in all probability — work even harder as an experiment director at the Payloads Operation Control Center (POCC) on the ground.

The launch, flight and landing of a Space Shuttle mission has often been described in magazines and books, even though the first scientific expeditions are still more than four years away. These details are not important here; what *is* important is that the Space Shuttle will open the road into space for scientists of all specialties — especially astronomers.

The next decade will open new frontiers of exploration and new opportunities for individual space missions. Even beyond the actual accomplishments of a decade that will see 100 astronomers venture into orbit, the 1980s will be the proving and training ground for scientists — full time astronaut-scientists who may have made their first space missions as payload specialists before being accepted into the full time astronaut corps — who will accompany the new lunar and interplanetary explorations of the 1990s.

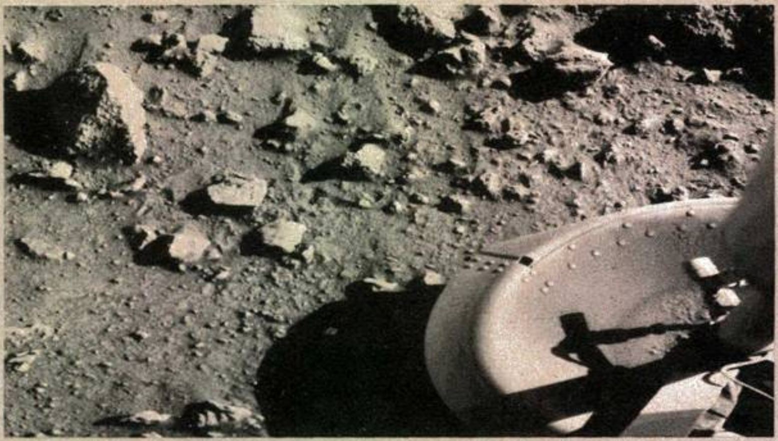
Astronomers have had their eyes on the skies and their minds and hearts in space for thousands of years; soon, their bodies will follow. Before the end of this century, some of them will be touching some of the objects they have studied for so long from afar.

Editor's Note: NASA headquarters has released an Announcement of Opportunity for scientists to join the Spacelab 2 mission to be flown in late 1980 — 3-1/2 years from now. The mission will emphasize astrophysics, astronomy, high energy astrophysics and solar phsysics. The mission will include a commander, a pilot, a mission specialist, and up to two payload specialists.

ASTRONOMY *is*. . .

galaxies

exploration

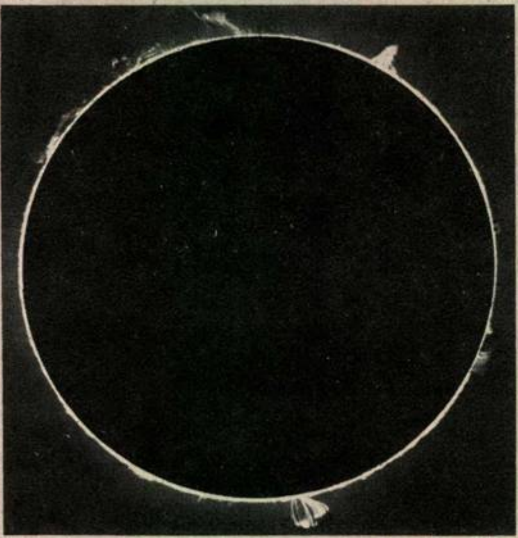


nebulae

comets

timeless

spectacular



dramatic

ASTRONOMY *is* The World's Most Beautiful Astronomy Magazine

Established August 1973. Published monthly by AstroMedia Corp.
Subscription price: 1 year (12 issues). $12. Canada & Mexico: $15 per year. All other foreign: $18 per year.
ASTRONOMY. 411 E. Mason St. - 6th Floor. Milwaukee. WI 53202. Phone (414) 276-2689

SKY ALMANAC

Lunar Eclipse Highlights April

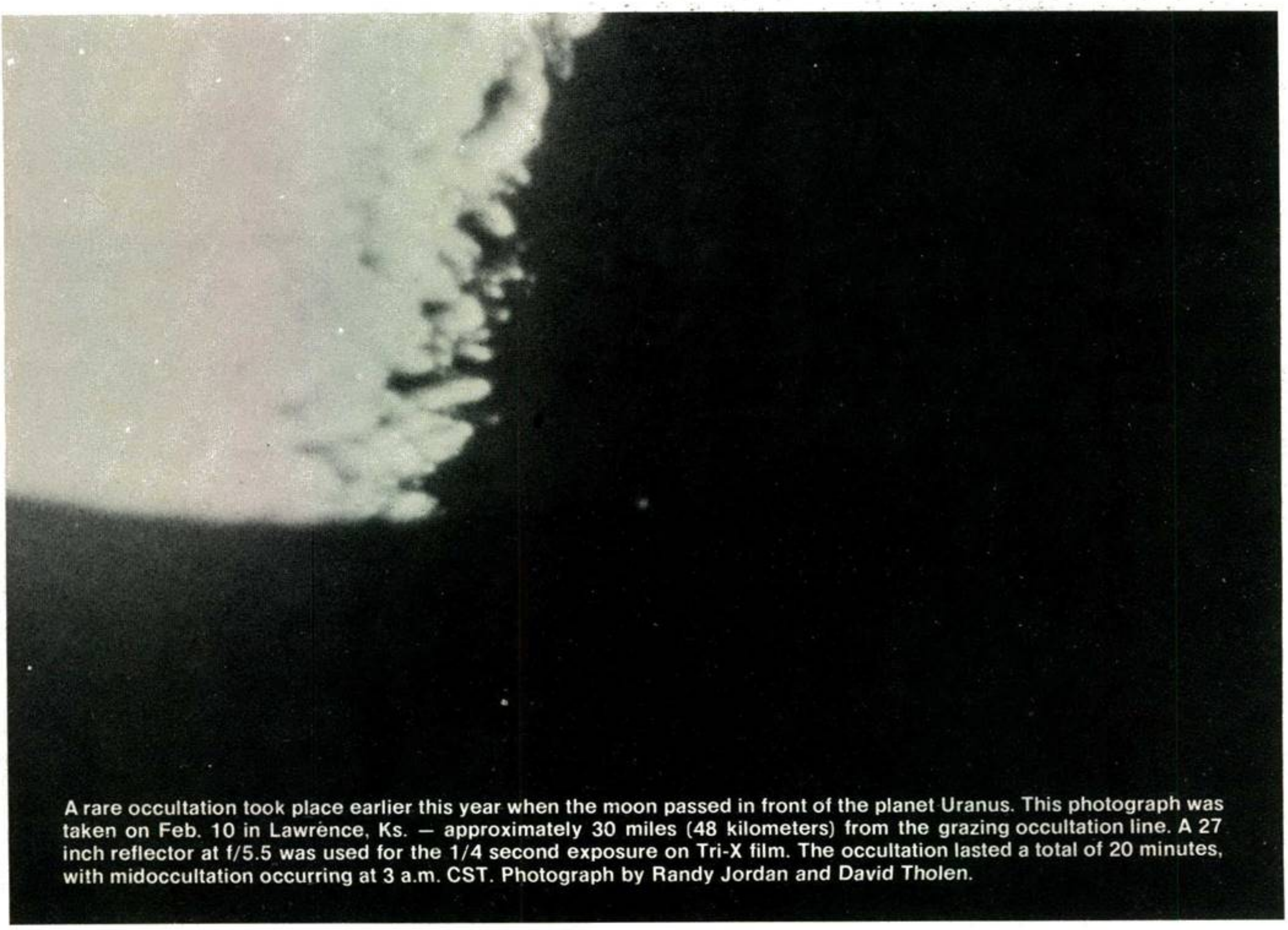
April is a month of hope, promising springtime and warmer weather. After one of the worst winters in history, astronomy enthusiasts may be tempted to venture out evenings — much more so than they would have in January. Unfortunately, there isn't much to observe: Planets are gradually getting dimmer and the major ones are moving into the morning sky. But observers will still have the Lyrid meteor shower and a partial lunar eclipse to look forward to.

Mercury

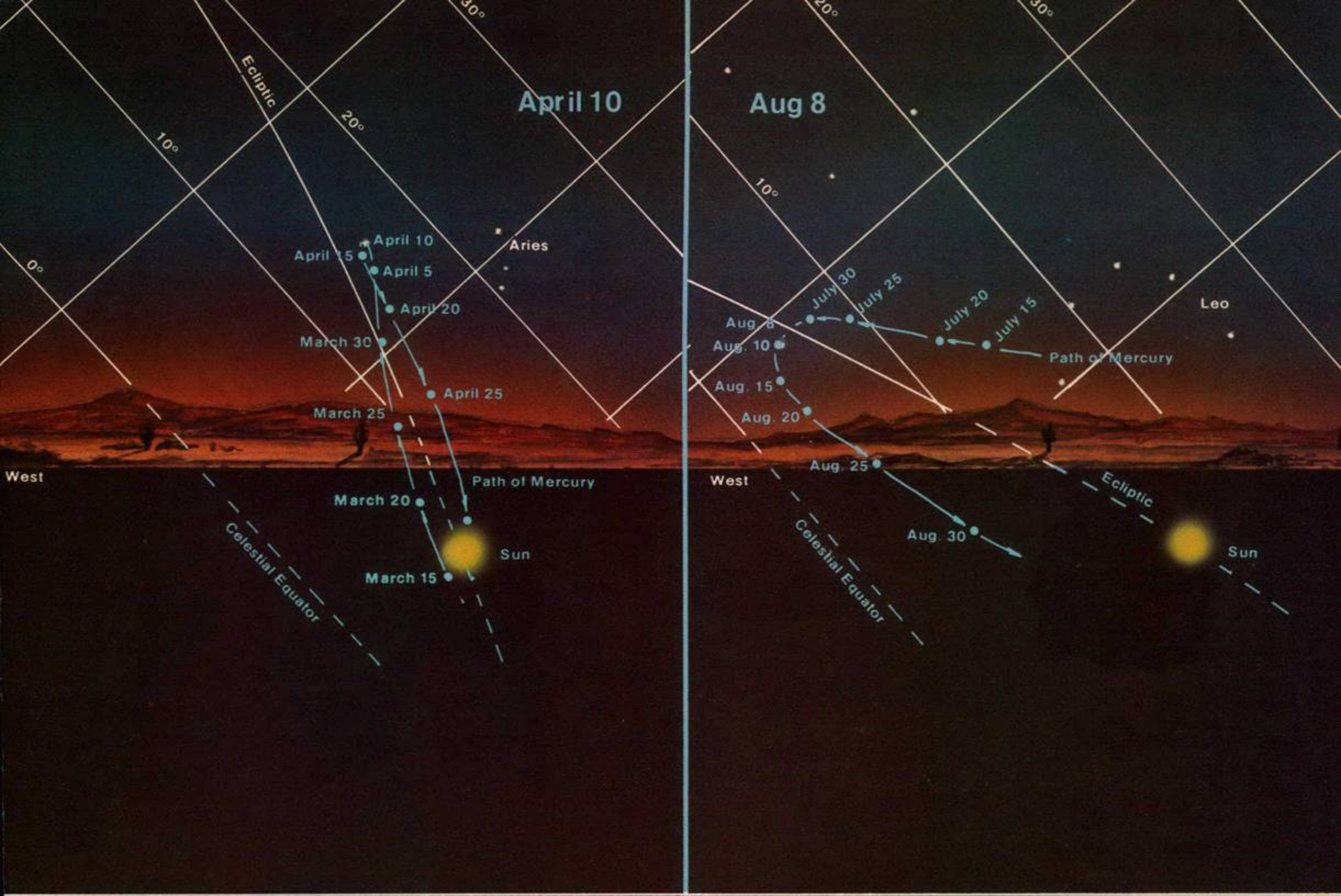
The elusive planet Mercury makes a highly visible appearance this month — one of the best this year. At magnitude 0.2, the planet will reach greatest eastern elongation on the 10th. It should be visible about 19 degrees above the horizon at sunset. During the month the planet will move closer to Earth; its distance from us decreases from 104 million miles (166 million kilometers) to 53 million (84 million). For an explanation of why it's easier to observe an eastern elongation in the spring than in fall — even though Mercury is farther from the sun in the fall — see the diagram on page 27 .

Venus

Venus moves its dazzling light display into the morning sky this month. The planet reaches inferior



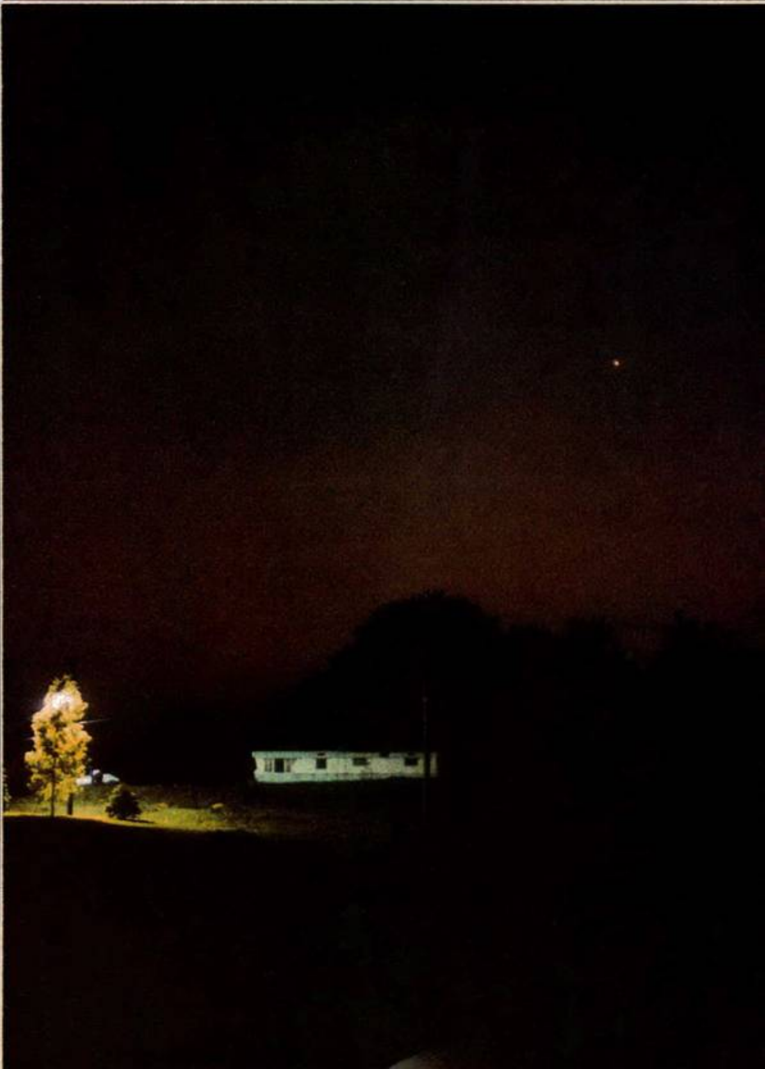
A rare occultation took place earlier this year when the moon passed in front of the planet Uranus. This photograph was taken on Feb. 10 in Lawrence, Ks. — approximately 30 miles (48 kilometers) from the grazing occultation line. A 27 inch reflector at f/5.5 was used for the 1/4 second exposure on Tri-X film. The occultation lasted a total of 20 minutes, with midoccultation occurring at 3 a.m. CST. Photograph by Randy Jordan and David Tholen.


April 10
Ecliptic
30°
20°
10°
0°
April 10
April 15
April 5
April 20
March 30
April 25
March 25
Aries
West
Path of Mercury
March 20
Sun
March 15
Celestial Equator
Aug 8
20°
30°
10°
July 30
July 25
July 20
July 15
Aug. 8
Aug. 10
Aug. 15
Aug. 20
Aug. 25
Aug. 30
Path of Mercury
Leo
West
Ecliptic
Celestial Equator
Sun

Above: The best times of the year for observing Mercury are when it is at eastern elongation in the spring (after sunset) and at western elongation in the fall (before sunrise). But there is a paradox here. At its eastern elongation this year on April 10, Mercury will be 19 degrees east of the sun. Later in the year at the eastern elongation on Aug. 8, it will be 27 degrees east of the sun. It would seem to be easier to see Mercury in August rather than April, and it would be except for one thing — the ecliptic. The path of the sun is lower in summer than in spring; therefore, it would be easier to observe Mercury in the spring. The reverse is true for western elongations; they are easier to observe in the fall than in the spring. Right: This photograph of Mercury was taken through a 205mm zoom lens on GAF 500 film exposed for three seconds at f/3.8. Photograph by Joseph Lehrer.

conjunction (between us and the sun) on the 6th, and toward the end of the month should be visible about an hour before the sun rises. An interesting fact to note is the change in magnitude before and after inferior conjunction. Venus reached greatest brilliancy (-4.3) on Feb. 28, 36 days before inferior conjunction when it was in the evening sky. As it approaches inferior conjunction it dims considerably from -4.3 to -3.1. Now as it enters the morning sky it will gradually brighten throughout the month of April, reaching greatest brilliancy again on May 11. The time period involved in these two dates is 36 days before and after inferior conjunction.

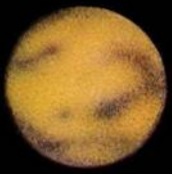
As the magnitude changes, so will the distance. Venus is closest to Earth at its inferior conjunction



Planet Finder

Ⓒ Ceres

April	1	15
R.A.	$12^{h}33^{m}$	$12^{h}22^{m}$
Dec.	+14°20'	+14°40'
Mag.	+7.1	+7.2



Ⓐ Mercury

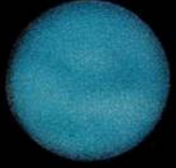
April	1
R.A.	$1^{h}42^{m}$
Dec.	+12°05'
Mag.	-0.8

Ⓑ Mercury

April	15
R.A.	$2^{h}41^{m}$
Dec.	+18°48'
Mag.	+1.1

Ⓜ Mars

April	1	15
R.A.	$22^{h}48^{m}$	$23^{h}28^{m}$
Dec.	-8°54'	-4°42'
Mag.	+1.4	+1.4



Ⓝ Neptune

April	15
R.A.	$16^{h}59^{m}$
Dec.	-21°11'
Mag.	+7.7

SUN

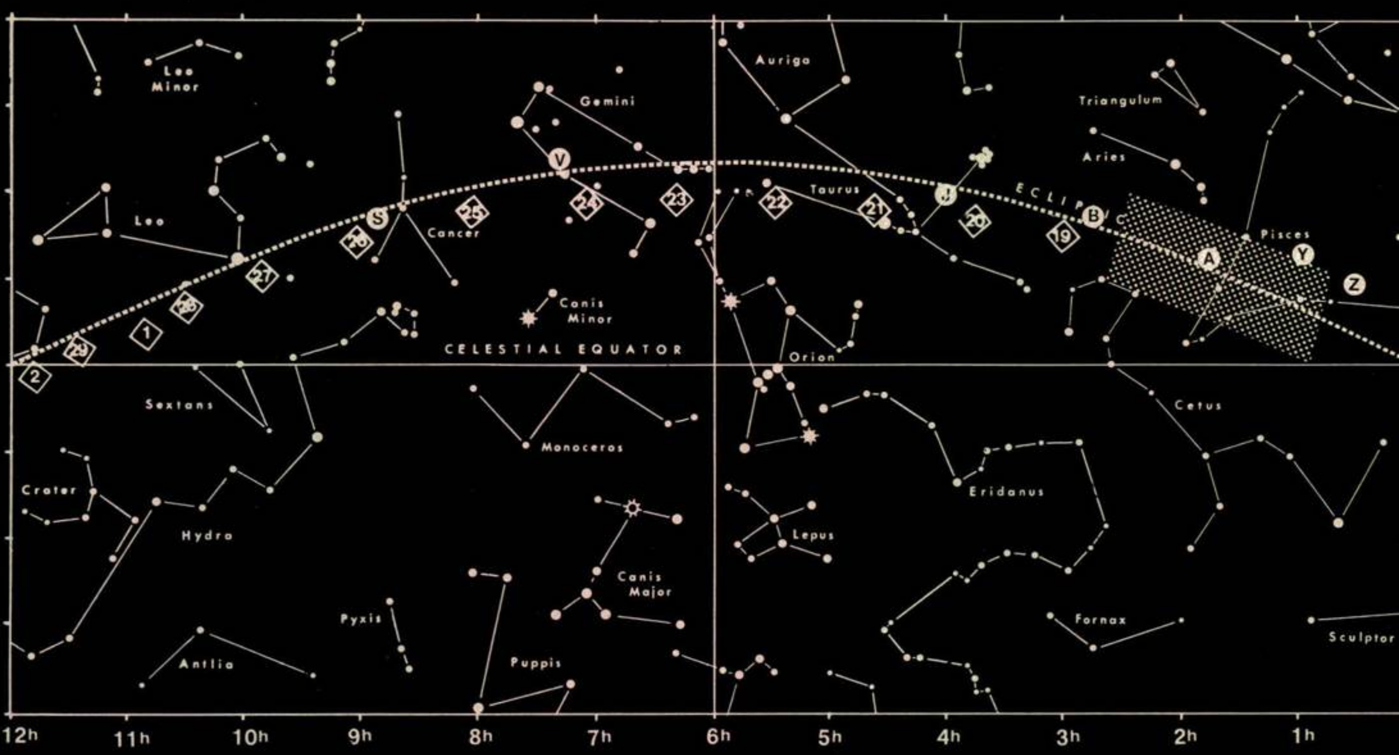
The sun is within the stippled zone throughout the month. Planets and stars near this area are not easily seen.

Ⓢ Saturn

April	1	15
R.A.	$8^{h}51^{m}$	$8^{h}50^{m}$
Dec.	+18°41'	+18°42'
Mag.	+0.3	+0.4

Ⓤ Uranus

April	15
R.A.	$14^{h}32^{m}$
Dec.	-14°29'
Mag.	+5.7


Leo Minor
Gemini
Auriga
Triangulum
Aries
Leo
Cancer
Taurus
ECLIPTIC
Pisces
Canis Minor
CELESTIAL EQUATOR
Orion
Sextans
Monoceros
Cetus
Crater
Hydra
Eridanus
Lepus
Canis Major
Pyxis
Fornax
Sculptor
Antlia
Puppis
V
S
J
B
A
Y
Z
1
2
19
20
21
22
23
24
25
26
27
28
29
12h
11h
10h
9h
8h
7h
6h
5h
4h
3h
2h
1h

The chart shows the positions of the moon, planets and brightest asteroids for the current month. Letters within the circles correspond to the letters beside each object in the data section above the map. Additional information about each object is given there. R.A. = right ascension and Dec . = declination, the two coordinates used to locate astronomical objects. The general coordinate system is indicated around the edge of the map. Mag . = magnitude, a

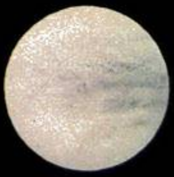
April 1977

Ⓥ Vesta

April	1	15
R.A.	7h03m	7h18m
Dec.	+25°59'	+25°43'
Mag.	+7.9	+8.1

Ⓙ Jupiter

April	1	15
R.A.	3h50m	4h02m
Dec.	+19°28'	+20°05'
Mag.	-1.6	-1.6



Ⓨ Venus

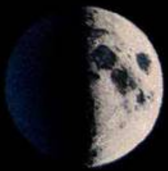
April	1
R.A.	0h57m
Dec.	+14°44'
Mag.	-3.3

Ⓩ Venus

April	15
R.A.	0h30m
Dec.	+9°36'
Mag.	-3.7

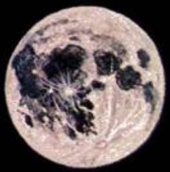
Ⓟ Pluto

April	15
R.A.	13h12m
Dec.	+11°23'
Mag.	+14



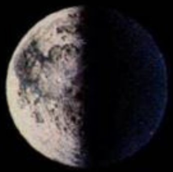
First Quarter

April 26



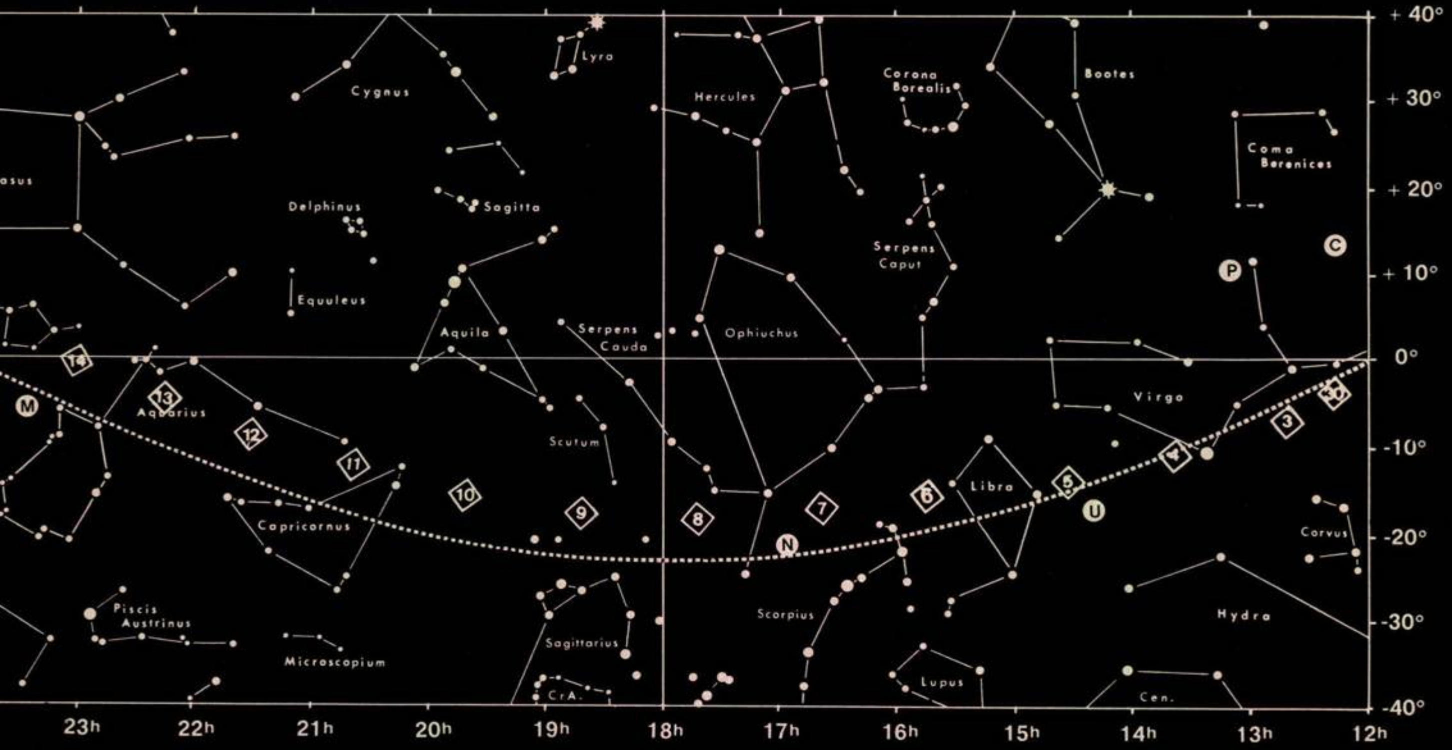
Full Moon

April 4



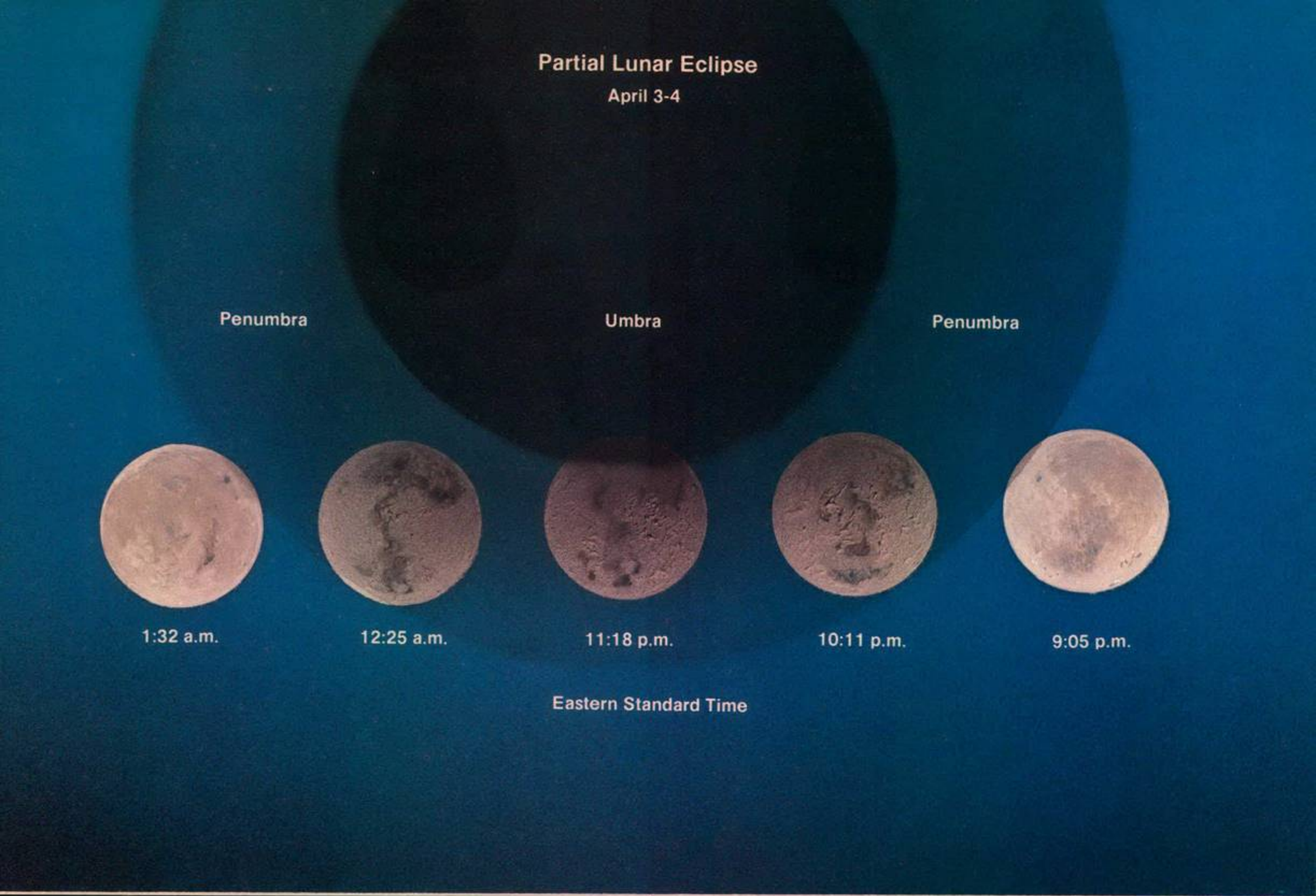
Last Quarter

April 10



asus
Cygnus
Lyra
Hercules
Corona Borealis
Bootes
Coma Berenices
Delphinus
Sagitta
Equuleus
Serpens Caput
Aquila
Serpens Cauda
Ophiuchus
Virgo
Aquarius
Scutum
Capricornus
Libra
Corvus
Scorpius
Hydra
Piscis Austrinus
Microscopium
Sagittarius
CrA.
Lupus
Cen.
M
N
U
P
C
1
2
3
4
5
6
7
8
9
10
11
12
13
14
+40°
+30°
+20°
+10°
0°
-10°
-20°
-30°
-40°
23h
22h
21h
20h
19h
18h
17h
16h
15h
14h
13h
12h

measurement of the object's brightness. (The minus magnitudes indicate very bright planets.) The diamonds with numbers within them indicate the position of the moon for each day of the month; the numbers correspond to the dates. Positions of the planets are for the 15th of the month except for Mercury and Venus which are shown on both the 1st and 15th. Certain areas of this map and the Star Dome chart overlap each month.



Above: This diagram shows the stages of the lunar eclipse at 67 minute intervals. At maximum, the shadow of the umbra should cover about 1/5 of the disk, not quite blacking it out so that observers should be able to see the rim through the umbral shadow. The eclipse will be visible throughout North America (except the extreme northwestern part), in addition to western Africa, South America, part of Antarctica and western Europe. Diagram by Mark Paternostro. Left: This 1975 photograph of a partial lunar eclipse was taken on High Speed Ektachrome (pushed to ASA 400) with a six inch Criterion Dynascope at f/8 for 1/50 second. Photograph by E.C. Kishkill.

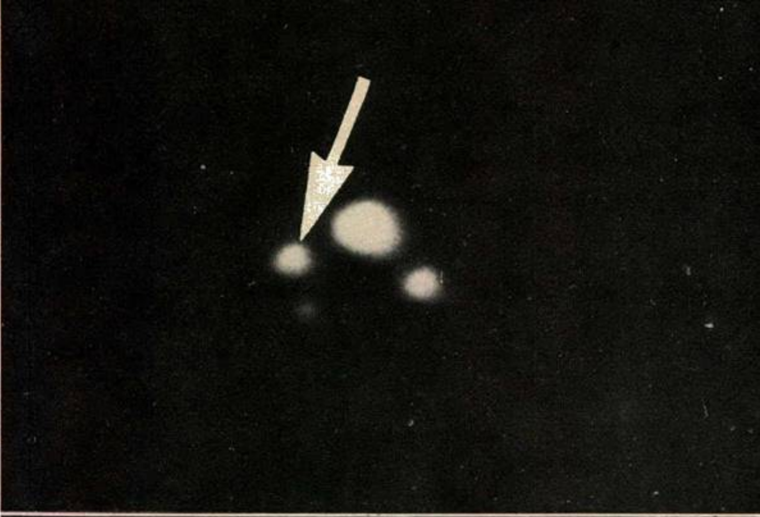
when it is 26 million miles (42 million kilometers) away. The planet begins to "speed up" and at month's end is 33 million miles (53 million kilometers) away.

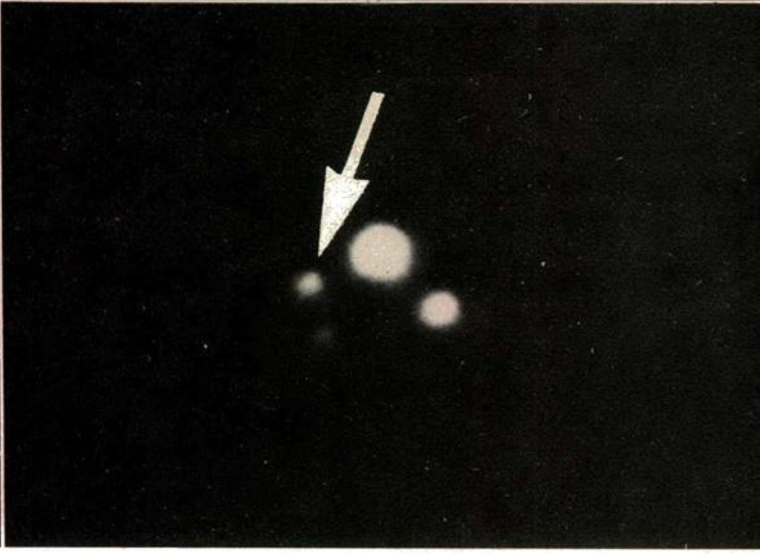
Jupiter

Jupiter continues moving away from Earth — from 526 million miles (841 million kilometers) in the early part of April to 552 million (884 million) at the end of the month. The planet is situated in Taurus; its magnitude is -1.6, and it sets about three hours after sunset. If you've become accustomed to viewing the splendor of Venus in the evening sky, you may be somewhat disappointed with having to settle for dimmer Jupiter as your evening star. But enjoy it while it's here; in a few weeks, it too will join Venus in the morning sky.

Saturn

Saturn does a slight turnabout in the early





Left: The Rosette nebula (NGC-2244) is pictured above in a 25 minute exposure on Kodak SO-410 film. A 5.5 inch Schmidt camera was used. Photograph by Christopher Bowland. Upper right: This photograph shows a relatively rare celestial event — an eclipsing variable in the Orion Trapezium. The variable, known as Theta Orionis A, ranges in magnitude from 6.7 to 7.7. It is shown at normal light on Dec. 17, 1976, in a 10 second exposure through a 10 inch Newtonian at f/5.6. Lower right: Theta Orionis A, photographed using the same procedure mentioned above, is shown at minimum light on Jan. 1, 1977. Photographs by David W. Hudgins.

part of the month. The planet ceases retrograde motion on the 11th, when it is stationary. After that date it resumes eastward motion relative to the stars, moving from 802 million (1,283 million) to 845 million miles (1,352 million kilometers). The planet is situated in the constellation Cancer and dims in magnitude slightly from 0.4 to 0.5 during the month.

Uranus, Neptune, Pluto

Uranus and Pluto will be at opposition on April 30 and April 2, respectively, while Neptune rises about midnight. For more information on these planets, see this month's Gazer's Gazette.

Lunar Eclipse

The partial eclipse of the moon on April 3 will be visible over all of North America except the extreme northwestern portion. This should be the better of the two lunar eclipses that occur this year (the second one is a penumbral eclipse in late September).

The eclipse stages and their times (Eastern Standard) are as follows: The moon enters penumbra at 9:05 p.m.; it enters the umbra at 10:30 p.m.; the middle of the eclipse is at 11:18 p.m.; the moon leaves the umbra at 12:06 a.m., and leaves the penumbra at 1:32 a.m. See the diagram on page 30 for an idea of how the eclipse will look. Photos of the eclipse are, of course, welcome at ASTRONOMY.

Lyrid Meteor Shower

Last year was not a particularly good one for major meteor showers, especially with the Perseids being wiped out by a full moon. This year things are definitely looking better, with the Lyrids and Perseids among the major meteor showers that will be reaching maximum during the new moon phase.

The Lyrids will reach maximum about 4:00 a.m. EST on April 22, but will also be visible for a few days before and after that date. The typical Lyrid is bright and leaves a shining tail. You should be able to observe about 15 per hour. The radiant point is just southwest of first magnitude Vega, on the border between Lyra and the constellation Hercules. The Lyrids follow the orbit of Thatcher's Comet, which swung past Earth in 1861 and will not return until 2276.

Announcing a 3-inch Unitron refractor with a 4-foot light path in a 19-inch tube.

To give you a high-resolution refractor that's as handy to carry as a portable typewriter, we've folded the light path in our totally new 3-inch Unitron Compact telescope. This unique instrument—the first of its kind commercially available—is housed in a tube only 19 inches long, five inches in diameter, travels in a case only 9 x 9 x 20 inches. All this without sacrificing the advantages of a refractor.

Because it's a Unitron you get an achromatic, air-spaced, multi-coated objective with a three-inch (75mm) aperture. The 3-inch Unitron Compact has a 1200mm focal length, f/16 focal ratio, 2.5 sec resolving power, 11.2 magnitude reach. Six coated eyepieces: 48x, 67x, 96x, 131x, 171x and 200x. The viewfinder is 8x, 30mm.

Sturdy tripod with famous Unitron equatorial mount has slow-motion controls on both axes, flexible cable control for right ascension, engraved setting circles, provision for motor drive. Precision rack-and-pinion focusing, erecting prism, star diagonal with achromatic amplifier, sun projection screen set, carrying case. All this for under $700!

Now we want to hear from you. Mail us your name and address and we'll send you a complete brochure, with samples of solar photography through the 3-inch Unitron Compact taken by well-known astro photographers. When you want a portable telescope but prefer a refractor, get the unique Unitron Compact.

Unitron Instruments, Inc.
101 Crossways Park West
Woodbury, N.Y. 11797. U.S.A.
(516) 364-8046

UNITRON The value line.

Unitron Instruments, Inc. **A–4**
subsidiary of
Ehrenreich Photo-Optical Industries, Inc.
101 Crossways Park West
Woodbury, N.Y. 11797. U.S.A.

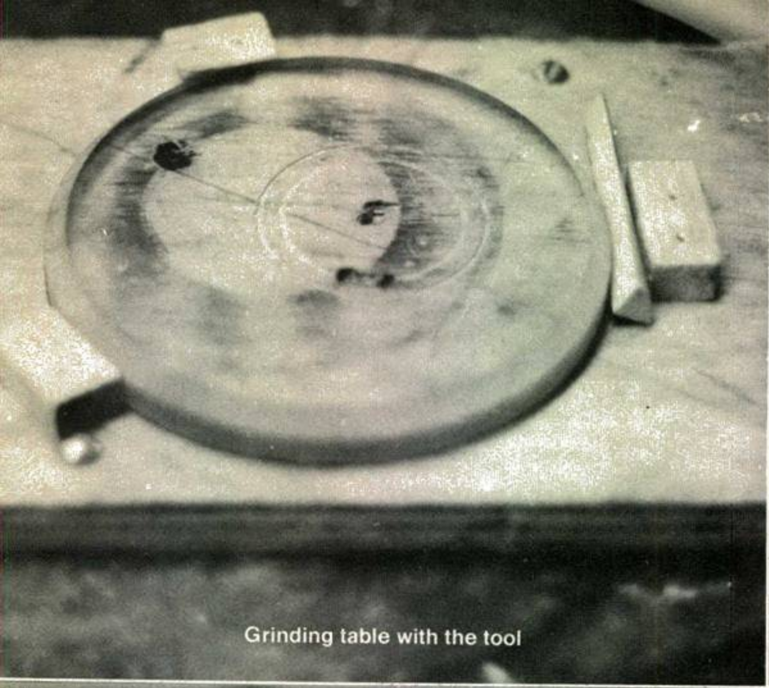
Clip out this coupon and mail for more information on this exciting new telescope!

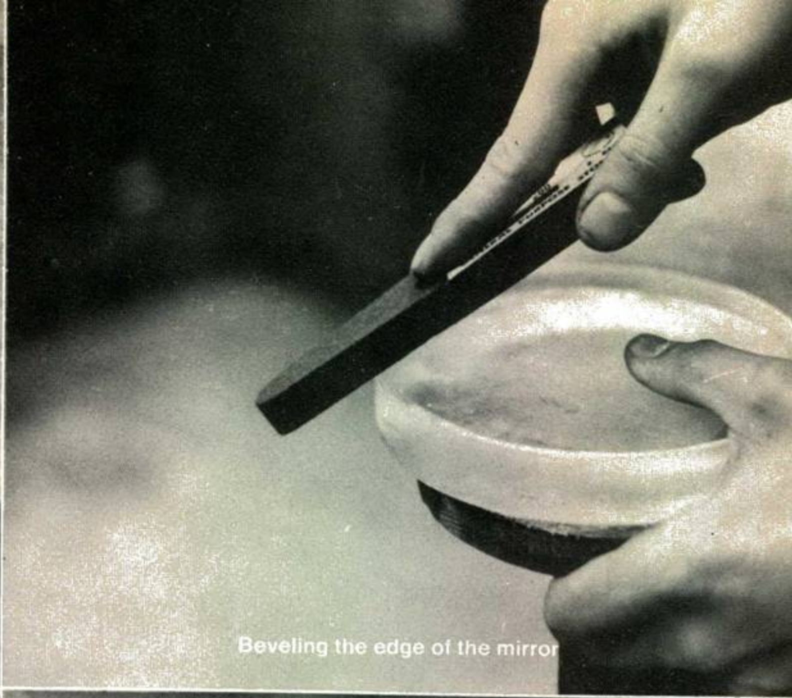
Name____________________

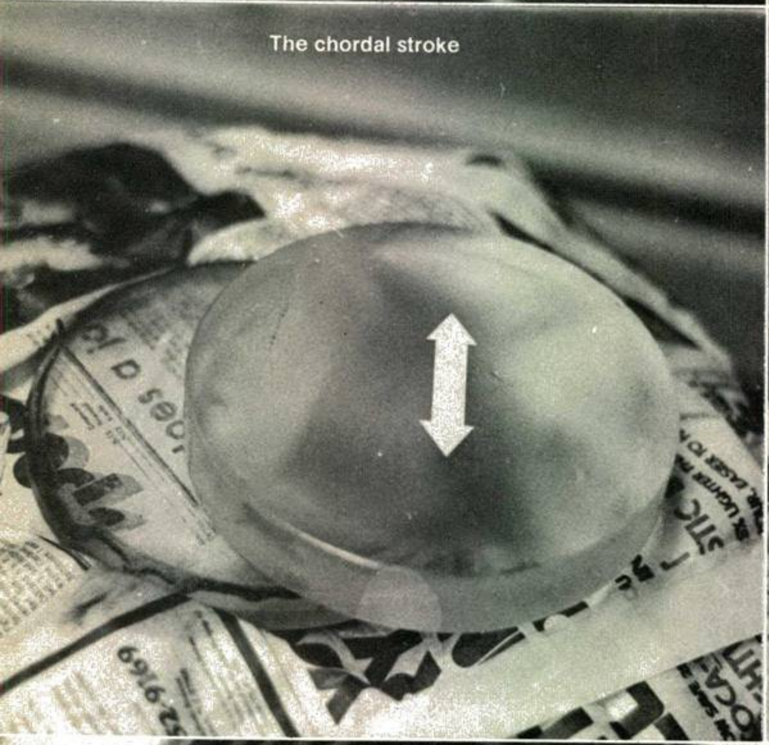
Address____________________

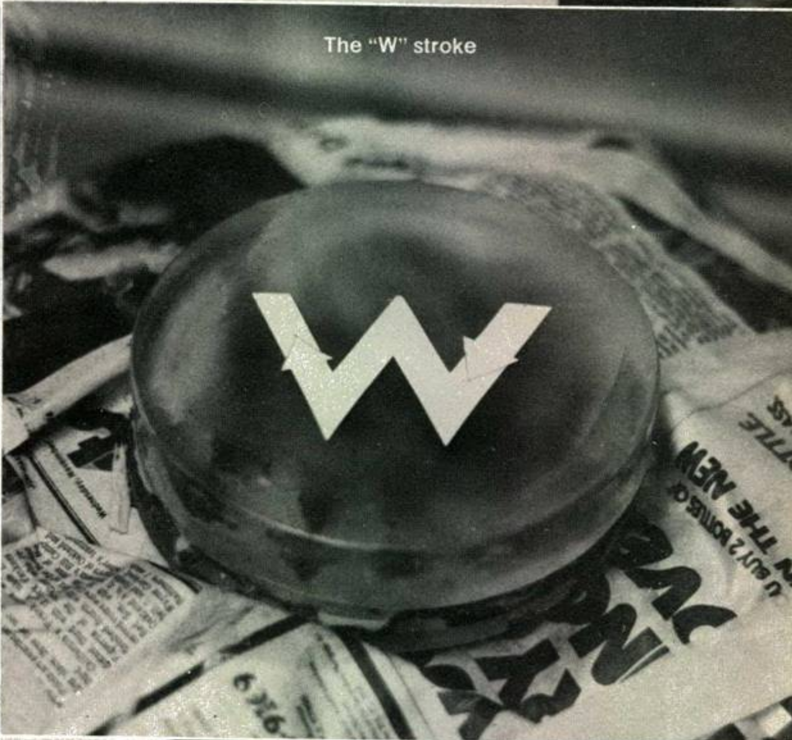
City____________________

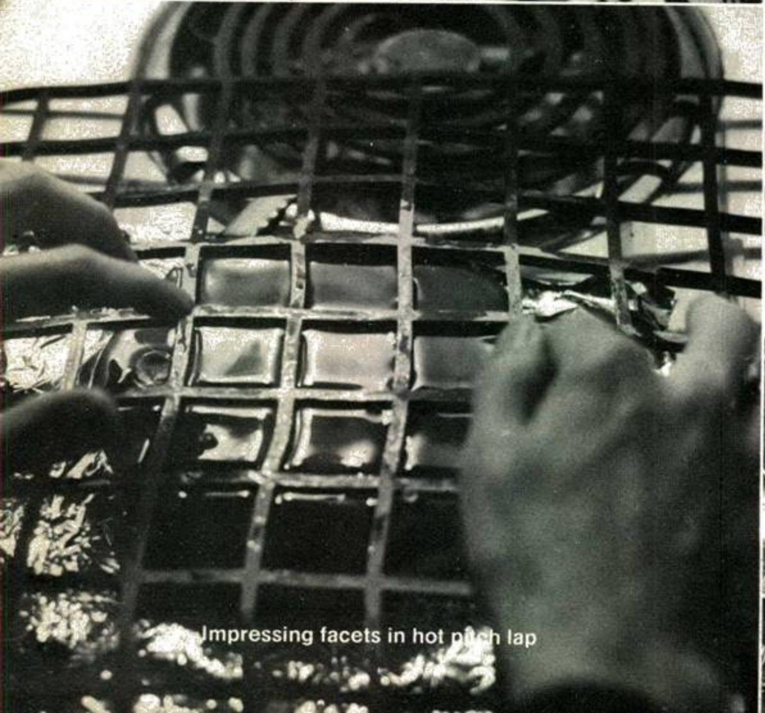
State____________ Zip________

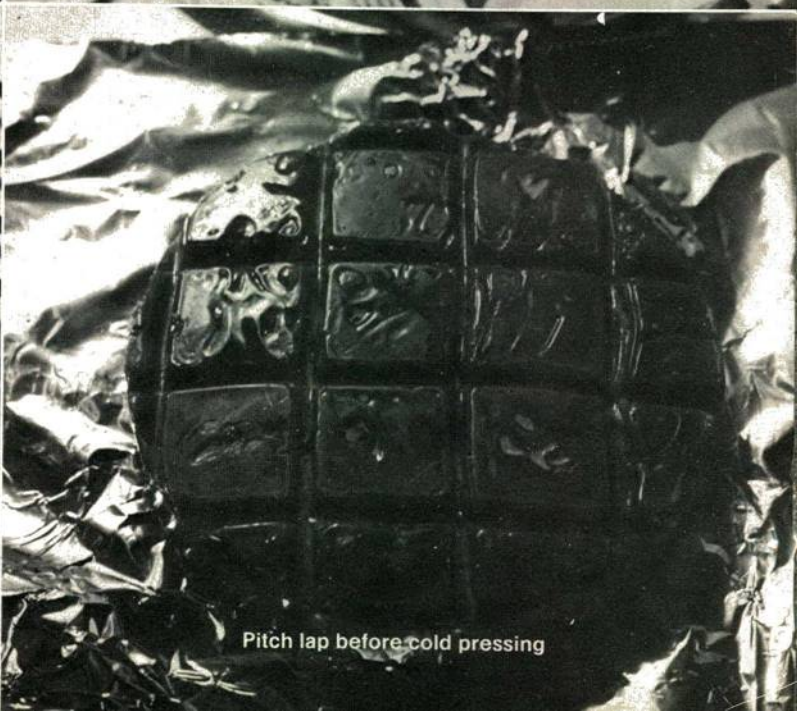

Grinding table with the tool

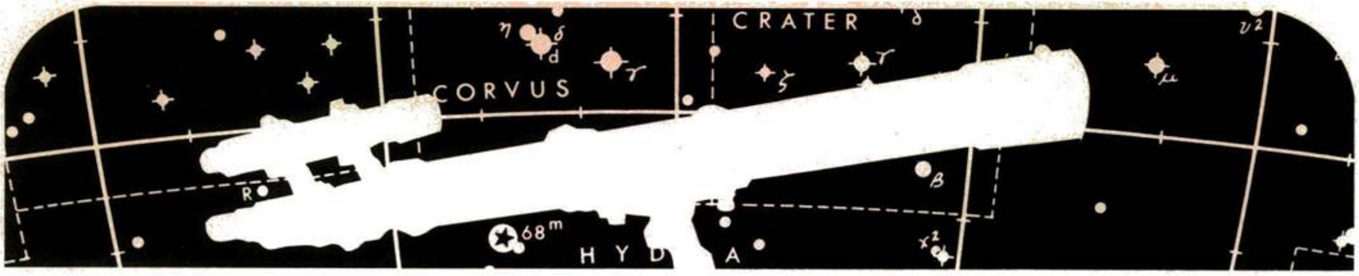

Beveling the edge of the mirror


The chordal stroke


The "W" stroke


Impressing facets in hot pitch lap


Pitch lap before cold pressing



Building A 6" Reflector

Part 1:

Grinding the Mirror

by
Alan P. Witzgall

Since the 1920s, tens of thousands of astronomy enthusiasts have built their own telescopes. Not only is making your own telescope lots of fun, but you'll save money while you learn how a fine instrument works. While you *can* build everything yourself, the best approach is to buy some parts, and build the others. In the next few issues of ASTRONOMY, we'll cover the whole telescope building process, starting with the most critical component — the mirror — and following with Equipment Atlas articles on building and buying everything else you'll need to construct your own high quality telescope.

Most of the homemade telescopes that have been built over the last half century have been Newtonian reflectors, and most have been six inchers with a focal length of somewhere around four feet. The reasons for this choice of size and focal length are that a six inch telescope is big enough for serious observing, but small enough to be simple to use, and it's big enough to show you the best views in the sky, but small enough to build easily. Therefore, the first two articles will describe the making of the optics of a six inch reflector mirror of f/8 or 48 inches focal length.

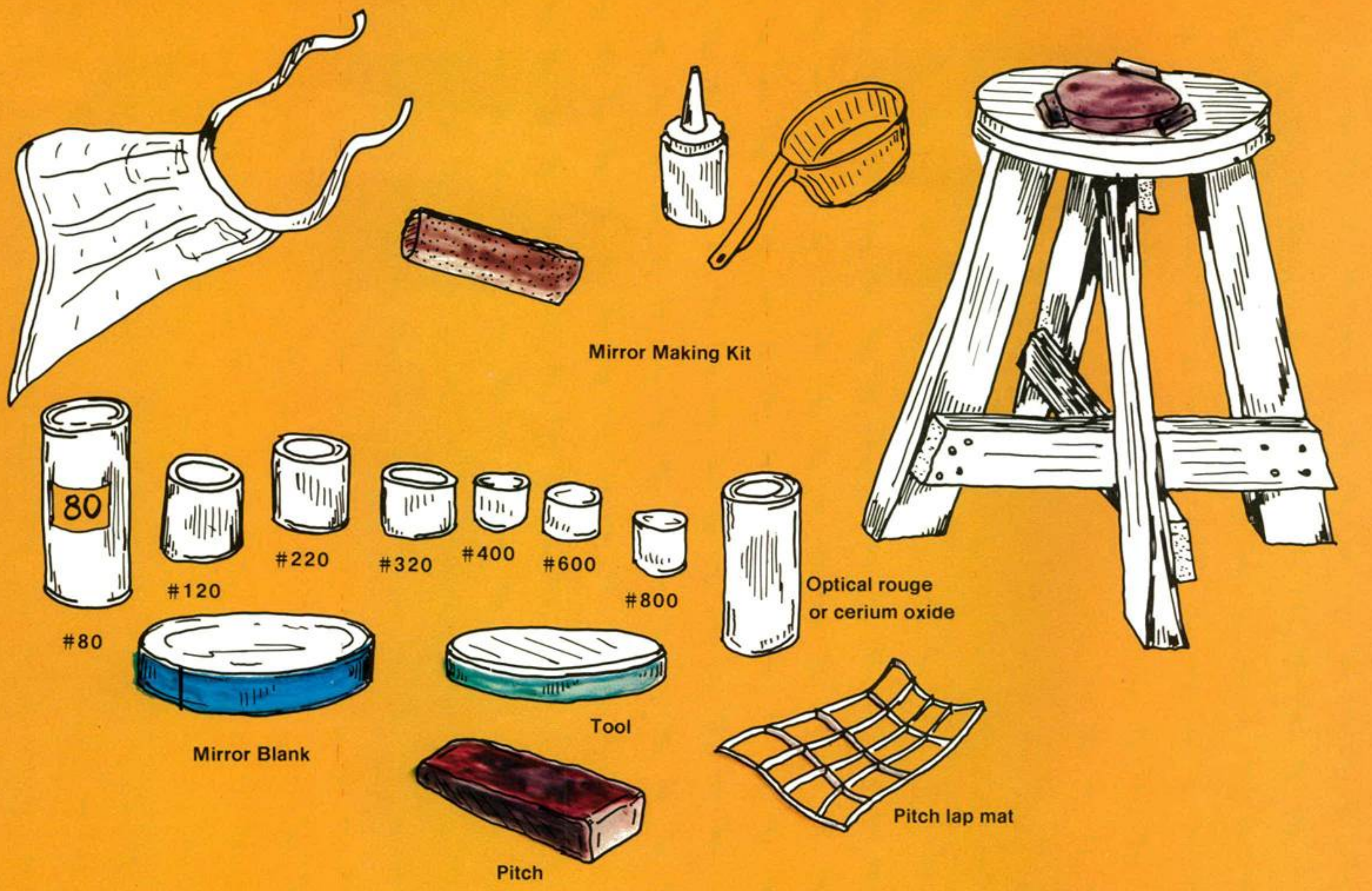
Contrary to popular belief, grinding a mirror is not a difficult project. Besides the raw materials, all you'll need is patience and a reasonable amount of care for details. We've divided mirror making into two parts: The first covers the rough grinding, fine grinding, and polishing of the glass. The second will describe how to test and figure the polished mirror from a sphere to a parabolic surface accurate to millionths of an inch!

For making a mirror, you'll need the following materials:

1) The mirror blank, which is usually made of Pyrex glass. Normal expansion and contraction of ordinary plate glass distorts the figure of a mirror to the point that optimum performance is rarely, if ever, achieved. Due to the much lower expansion properties of Pyrex glass, this effect is minimized. The thickness of the blank is about one inch to reduce the chance that the mirror itself may deform slightly from Earth's gravity.

2) The tool, a disk of plate glass or Pyrex; all grinding actions are performed directly on its surface. For polishing, its convex surface is coated with a soft layer of pitch. The thickness of the tool should not be less than 3/4 inch, since during grinding the tool bears all the grinding force.

3) Abrasives — either aluminum oxide or silicon carbide in sizes from #80 (the coarsest) to #1000 (the finest). The #80 is used for "excavating" the curve into both tool and mirror. In the process, the curved surface will be covered with pits, each about 1/80 inch across. To remove them we use #120, 220, 320, 400, 600 and either 800 or 305E — each finer abrasive grinding the mirror finer and finer.



4) Polishing pitch. Even after you use the finest grade of abrasive, you'll still have tiny (1/10,000 inch) pits in the surface of the mirror. To remove them (by moving the molecules of glass), you'll coat the surface of the tool with pitch for polishing. The pitch is crisscrossed in an off-centered network of channels, so that polishing agents and air can flow.

5) Polishing agent. Most manufacturers will supply red optical rouge as a polishing agent. Although an excellent agent for figuring a mirror, it is rather slow for the initial polishing. To speed up your polishing, buy a container of cerium oxide polishing agent. Many companies sell mirror grinding kits that contain all of the materials mentioned above.

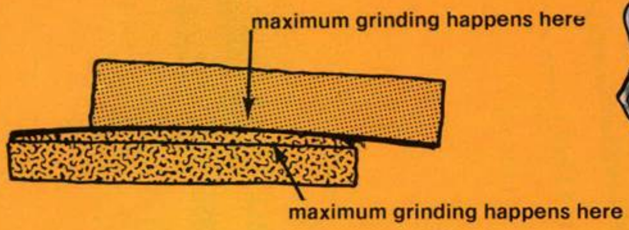
6) Miscellaneous "bits and pieces" such as a plastic apron to shield the worker from splattered spent abrasive and polishing agent (the plastic is also easier to rinse free of contaminating matter than a cloth's interwoven threads); several rolls of paper towels; a grindstone, 2 x 9 x 1/2 inches; a squeeze bottle for dispensing water accurately; an old saucepan — or better yet, a tin can that's been completely cleaned; a heat source (a hot plate is excellent here), and lots of old newspapers.

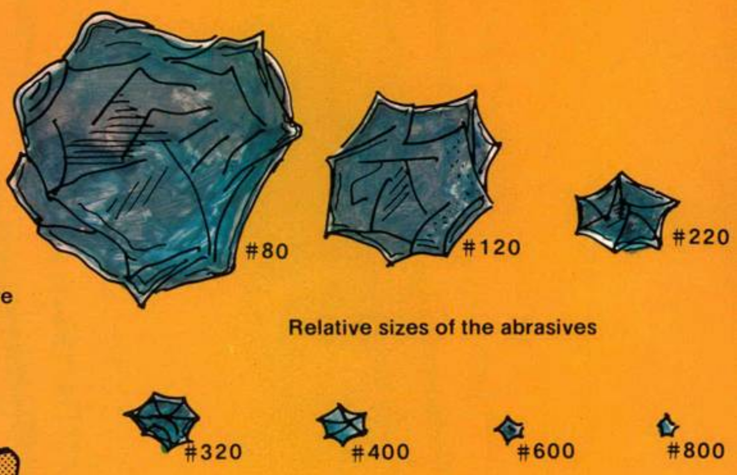
You'll also need a place to work, and a stand or table to work on. The grinding/polishing stand can be a steady corner of, or a specially built, small table, or even the top of a 55 gallon drum, filled 1/4 of the way with water. Whatever you use, the stand *must be rigid*; in many cases, your full weight will push across its top.

Nail or bolt a 12 inch square piece of 3/4-inch-thick plywood, sealed watertight with shellac or Flecto-Varathane, to the top of your grinding stand. On it draw a six inch circle. Nail two cleats of 1 x 2 x 3/8 inch thick plywood (also sealed) tangentially to the circle, 120 degrees apart. Nail a third cleat about 3/4 inch from the edge of the circle. Use a fourth wedge shaped piece of plywood to hold the tool securely in place.

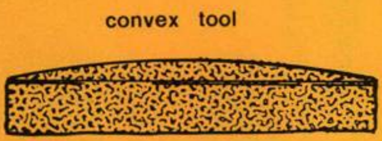
Before grinding, you'll have to bevel the edges of mirror and tool to keep chips from developing along the edges. Holding the grindstone on a 45 degree angle to the edge of the wet blank and tool, grind a 1/8 inch bevel on the edge of the mirror blank and one of 1/4 inch width on the tool. Use heavy, slow strokes away from yourself with plenty of water on the grindstone. After the bevel has been made, "round" the edges of the bevel by using the grindstone once or twice around the edge on a very shallow angle.

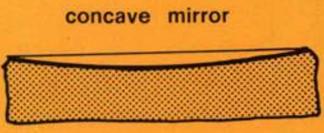
Now you're ready to start grinding. Place the beveled tool on the grinding table (with beveled side facing up) on top of a layer of dampened newspaper

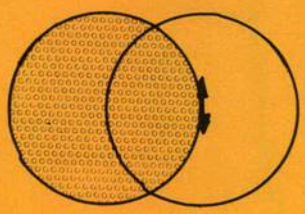


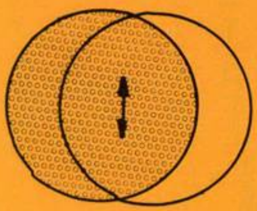


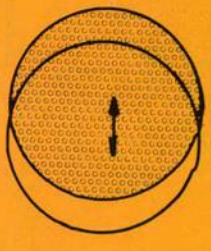
Relative sizes of the abrasives

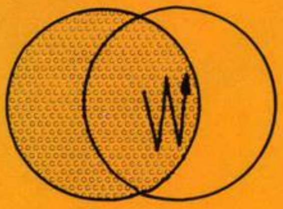





Chordal stroke


"Mild" chordal stroke


Normal center-over-center stroke


"W" stroke

already in the holder. Using the wood wedge, snugly brace the mirror against the cleats. The paper protects the wood from contamination and also helps prevent strain from being placed on the tool.

Rough Grinding

Using your coarsest abrasive (the #80 grit), place about 1/4 teaspoon of abrasive on the tool, spreading it out evenly over its face. Add about 1/4 teaspoon of water to it. Place the mirror, with bevel facing down, on the abrasive charged tool. Now you're ready to begin grinding.

Of several grinding strokes commonly used, the fastest is that called a *chordal* stroke. The center of the mirror follows chords of varying length across the face of the tool. The center of the mirror and the edge of the tool wear the fastest when you grind this way. What you are trying to do is simple: You will make the mirror *concave*, and the tool *convex*.

Use the weight of your body in the grinding of the mirror. The more weight applied at this stage, the faster you'll be able to dig a concavity into the surface of the mirror. Also, you'll find the faster you wear out the curves in this way, the faster you'll need to replace the used abrasives. Therefore, when that terrific rough grinding noise wears down to a "shushing" sound, wipe the tool free of grit and apply another "wet" of abrasive and water.

At the same time you push the mirror back and forth, you have to turn it a bit with each stroke, and simultaneously walk slowly around your grinding stand. At the middle and end of each wet you should also rotate the tool. After about 30 minutes of this, or about 10 to 15 wets, wash off both tool and blank and check what has happened. The edges of the tool should have a rough, pitted, gray appearance, as should the center of the mirror. A straight edge, held against the mirror, will reveal the embryonic concave of your mirror. The depth of this curve can be correctly measured with an accurate ruler, with the straight edge as a guide.

How deep do you need to grind? It depends on the focal length of mirror needed. To find the *sagitta* (as this depth is called), we employ this formula:

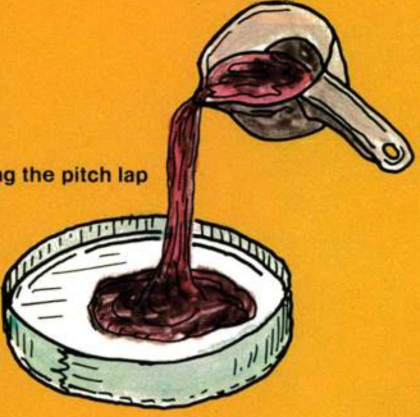
$$s = \frac{r^2}{2R}$$

s = the depth of the curve
r = radius of the mirror
R = the radius of curvature of the mirror, or twice the focal length

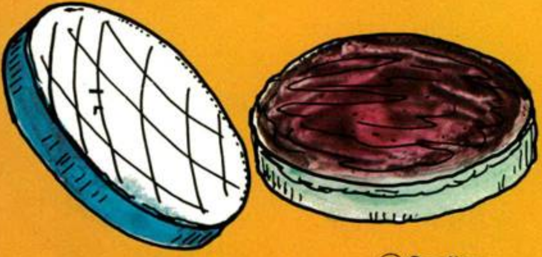
For a six inch f/ 8 reflector of 48 inches focal length, we have:

$$\frac{(3)^2}{2(2\text{x}48)} = \frac{9}{192} = \text{(0.0469 = depth of sagitta), or about 1/25 inch (1mm)}$$

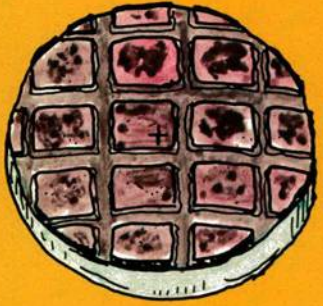
Continue grinding until the sagitta begins to approach the value desired. As it does, move the

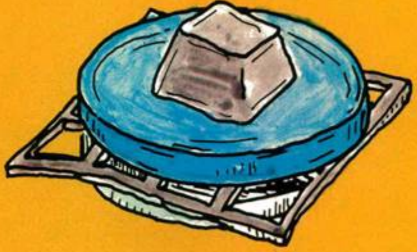


① Pouring the pitch lap

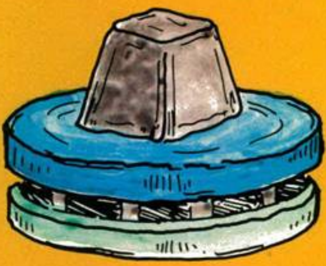


② Cooling





③ Forming the lap



④ Pressing facets

center of the mirror closer to the center of the tool and continue grinding until the gray, abraded central area on the mirror extends farther toward the edges. By then, the gray areas on both tool and mirror should extend over all their surfaces.

At this point, you'll want to find the focal length of the mirror, give or take an inch. Stand the mirror on its edge and splash soapy water on its surface. Using a light bulb on an extension cord, get the image of the bulb in the reflection of the mirror. Bob the light slightly up and down. If the reflected bulb appears to do the same,you are closer than the radius of curvature (R.O.C.). If it goes opposite from the motion of the bulb, you are outside the R.O.C. Try to find a point where no apparent motion is seen, and it just goes on and off. Mark this point: 1/ 2 this distance is the focal length of the mirror! Another very easy way is to wet the mirror outside on a sunny day, and locate the image of the sun formed by the wet mirror. The distance from the mirror to the smaller solar image is the focal length.

If the focal length is more than 10 inches longer than you wish, return to a mild chordal stroke, with the center of the mirror half the distance to the edge of the tool. Grinding center over center (diametrically) with pressure is probably the best bet to save time and effort. If the focal length is *too short*, place the mirror on the bottom and grind within a half "W" stroke; that is, the tool's center traces out a "W" on the mirror, with a one inch overhang on any side (a total of two inches overhang, or 1/3 the diameter of the mirror). Test every 15 to 20 minutes for the changing focal length. Remember to keep turning the mirror every few strokes, walking around the grinding stand, and rotating the tool two or three times per wet. This will keep your curved mirror surfaces accurately round — that is, the figures of revolution.

When you arrive at the desired value, you must smooth out the curve. Look through the mirror on the tool; you'll notice the pattern of the bubbles between the mirror and tool. If they are small and randomly distributed, you have achieved good "close contact" between tool and mirror. If they are large or grouped in the center of the mirror, use a 1/3 "W" stroke to even out and bring together the two curves. If you fail to do so now, the chances are that the slower acting, finer grits will never be able to do it. Total grinding time (roughing and smoothing) should be about four to six hours for an f/8. The pressure you need to apply is much less now that the curve is formed; just the weight of your arms and hands will be sufficient. You'll find the abrasive lasts a lot longer now — for two or three minutes — before you feel the grinding has stopped.

Once good contact is achieved and your desired focal length is close (plus or minus 10 feet), it's time to clean everything up. All clothing, aprons, *anything* that's touched abrasive must be washed clean of any spent abrasive. Scrub the edges and rear surfaces of the tool and mirror with a clean sponge and soapy water to dislodge any leftover grit. Use a stiff brush on the grinding stand and work at the cracks. If necessary, give it another coat of shellac (to seal in the #80 grit you can't remove).

Fine Grinding

As before, set up with a clean sheet of newspaper. Now you'll use #120 grit to fine grind out the deep pits left by the #80 grit. Not very much pressure is needed here; the weight of your hands alone is usually sufficient. From now on you'll use a 1/3 "W" stroke.

After a total time of one hour, wash off the mirror, and with a powerful magnifying lens (usually supplied in the kits) carefully examine the pitted surface of the mirror. Be sure that all the pits are about the same size. If any larger ones remain, grind another 20 minutes, with light pressure as before and a 1/3 "W" stroke. This should remove them.

The same procedure, including a thorough cleanup, all precautions and grinding strokes, hold for all the rest of the abrasives. Each wet will last longer (5 to 10 minutes) and will leave smaller pits. After one hour's time with each, clean off the area of spent abrasive and check that all big pits have been ground away. If they haven't, continue for another 30 minutes and then check again. Whenever you switch to a finer abrasive, clean *everything* thoroughly. When you reach the finest abrasives — the #600 and #305E (or #800), take care not to stick the disks together. If you feel them clinging together as you grind, add a bit more water and abrasive. If they do stick, place them in lukewarm water for 15 minutes, then in a refrigerator for 20 minutes. After about 20 minutes, the different expansion properties of the glasses should force the two disks apart without damage. A more dangerous technique is to tap the mirror very gently (with the tool braced in the stand) with a thick piece of wood.

When you finish with the finest grade abrasive, the mirror's ground surface should feel like velvet and the slightest moisture should make it transparent. With an eyepiece or strong magnifier, check out the surface of the mirror for large residual pits. A few will not effect the mirror's performance, but if you see pits or a gray appearance near the edge or center of the mirror, you didn't maintain contact all over the surface of both disks. You have no choice but to return to #220 abrasive and use the 1/3 "W" stroke *with pressure* for about one hour, and then proceed back through the rest of the grits. It's best to do the job of getting contact correctly the first time.

If all the criteria (none or very few shallow scratches, few large pits, an even and almost transparent "mist" on the mirror) are met, you are ready to proceed with preparations for making the pitch lap and preliminary polishing of the mirror.

Polishing is different than grinding. In grinding, you removed glass to form a curved surface. Polishing is a shifting of glass molecules which eventually fill in very tiny pits and scratches left by the finest grit. In polishing, the particles of cerium oxide or rouge embed themselves in optical pitch. The shaving action of their sharp edges, together with frictional heat, move the glass to form a perfect smooth surface.

Making a Pitch Polisher

Take the saucepan or tin can and place your piece of pitch in its bottom (break the pitch into pieces if necessary). Heat it over *very low heat* on an electric stove — or better yet, in a double boiler. Be careful here, as the volatile substances (turpentine) in pitch are very flammable. Stir the melted pitch to remove the bubbles that may develop. *Warning: If you have to use a flame for heat, be very, very careful.*

While the pitch is melting, wrap the edges of the tool with adhesive paper tape (creating a lap), leaving a 1/4 inch high rim over the actual surface of the tool. Wipe the surface of the tool with a wad of cotton dampened with turpentine— this aids the pitch in sticking to the glass. Place the mirror in lukewarm water to raise its temperature above that of the room.

For proper polishing, you must make sure the pitch is of the proper hardness. Do this by taking 1/2 teaspoon of the melted pitch and cooling it quickly in cold water. Press your thumbnail (with your elbow resting on the table) with a force of about one to three pounds on the pitch. If, in 10 seconds, a 1/16 inch groove is depressed in the pitch, it is satisfactory to use. Usually it is the correct hardness as the manufacturer has supplied it. If too soft, heat the pitch for five more minutes and try to test again. If too hard, add one or two drops of turpentine — *no more!* — and stir and test again. Remember pitch is flammable; do all tests well away from the stove or hot plate.

When the proper hardness is achieved, pour the melted pitch into the lap, allowing it to flow right up to the rim, so that it appears to bulge above the paper border. Let this cool for two to five minutes — long enough that it can stand by itself without the paper. During this time, take the mirror from the warm water bath, dry it, and smear it with a thick gluey paste of water, a liquid soap and cerium oxide or rouge polishing agent.

Strip away the paper tape by pulling it from the edge of the lap in sharp, tangent actions. Coat its surface with the cerium oxide-soap-water mixture, place the mirror centered on the pitch, and then immediately de-center the mirror, moving it to

EQUIPMENT ATLAS *continued on page 54*

Meade Instruments: fastest delivery in the West... or East

As America's number one supplier of telescope accessories, our watchword is ***service.*** Whether placed by phone or mail, your order is shipped by First Class Mail or United Parcel Service within 24 hours. Our inventory of eyepieces, filters, camera adapters, viewfinders, and other telescope parts is the largest in America. Ready for the fastest delivery in the West. . .or East.

MEADE Research-Grade Eyepieces

A few words from our customers . . .

I am not only pleased but rather astounded by the optical perfection of your Research-Grade eyepieces.
Peter Armato Sparks, Nevada

My son made me a present of one of your Research-Grade 10.5mm oculars. It has performed magnificently, and far ahead of any other eyepiece I have ever used, even in the besodden atmosphere we have here in the Ohio Valley.
Donald J. Smith Shadeyside, Ohio

I am now using a Research-Grade Erfle 20mm purchased from your firm recently on my Celestron 14 and find the ocular is all that you claim and more. It reveals delicate color contrasts on Saturn superbly, as well as globular clusters, nebulae, and double stars.
Norman J. Boisclair Rensselaer, New York

I appreciate the fast shipment of the 20mm Research-Grade Erfle, which was in my hands 4 days after I mailed the order! I would also like to say that the eyepiece is the finest I have ever used, borrowed or seen, and I have seen many in the 15 years I have been an amateur. In the future I intend to convert my battery of eyepieces to Meade Research-Grade orthoscopics, the sooner the better.
Jim Schultz Lyons, Colorado

Let me mention how pleased I am with your products and the very prompt service I have received. I am especially excited with your Research-Grade 20mm Erfle. Its incredible field of view and flatness of field make it perfect for my variable star work. It is truly breathtaking with deep-sky objects. The real surprise came when coupled with your Research-Grade 2X Telenegative Amplifier . . . truly a fine optical achievement.
James L. Ferreira Fremont, California

MEADE Research-Grade Eyepieces (1¼" O.D.)
Multi-Coated • Parfocal • Threaded for Filters

Orthoscopic 4, 7, 10.5, 16.8, 28mm . . . each	$ 29.95 ppd.
Erfle 20mm.	36.50 ppd.
Set of any 4 Orthoscopics, with case	112.50 ppd.
Set of any 4 Orthoscopics plus Erfle 20mm, with case	137.50 ppd.
Full set of 5 Orthoscopics plus Erfle 20mm, with case	165.00 ppd.

Rack-and-Pinion Focusers - Three superbly engineered focusers. Thousands in use by amateurs everywhere. *See Items #21, 22, 23.*

Camera Adapters - Precision machined adapters for quick attachment of cameras to your telescope. *See Item #20.*

Zoom Orthoscopic Eyepiece-8.4-21mm (1¼" O.D.). *See Item #8.*

2" O.D. Eyepieces - *See Items #10, 11.*

7 x 50 Right-Angle Viewfinder
Fine wide-field finder for both straight-through and right-angle viewing. *See Item #31.*

Series 1 Orthoscopic Eyepieces (1¼" and .965" O.D.) - Classical 4-element design, 45° field, available in 8 focal lengths. *See Items #2, 3.*

Research-Grade Orthoscopic Eyepieces (1¼" O.D.) - Multi-coated, 4-element, parfocal. The finest astronomical eyepieces obtainable. *See Item #4.*

Series 1 Kellner Eyepieces (1¼" O.D.)
Fine performance at a moderate price. Two 40mm wide-field models available. *See Items #5, 6.*

Illuminated Reticle Eyepiece-For precise photographic guiding and accurate measurement of angular distances. *See Item #14.*

2x-3x Telenegative Amplifiers - The world's finest Barlow lenses, 26mm clear aperture, 1¼" O.D. *See Items #16, 17.*

PRODUCT DATA

1 - PHOTO-VISUAL COLOR FILTERS - Top quality optical glass, dyed in the mass, with excellent spectral homogeneity. Mounted in machined metal cells which thread directly into all our 1-1/4" "Series 1" and "Research-Grade" eyepieces. Filters may be piggybacked. Listed by Wratten No. and color:
#8 Light Yellow - #11 Yellow-Green - #12 Yellow - #21 Orange - #23A Light Red - #25A Red - #47 Violet - #58 Green - #80A Medium Blue - Polarizer (30% transmission) Each Filter:...**$4.95 ppd.** - Set of any 6:...**$28.50 ppd.** - Full set of 10:...**$46.50 ppd.**

2 - Series 1 ORTHOSCOPIC EYEPIECES (1-1/4" or .965" O.D.) - These Meade eyepieces are the largest selling orthoscopics in the world. Classical 4-element design, 45° field, fully coated, with precise corrections for color and field flatness. All 1-1/4" barrels are threaded to accept our photo-visual filters directly. **Focal lengths: 4, 5, 6, 7, 9, 12.5, 18, 25mm - Each...$17.95 ppd.**

3 - Series 1 PARFOCAL ORTHOSCOPIC EYEPIECES (1-1/4" O.D.) - As in (2) but parfocalized in all 8 focal lengths. **Each:...$19.25 ppd.** - **Set of any 4:...$72.95 ppd. Set of any 5:...$90.00 ppd. - Additional eyepieces: each...$18.00 ppd.**

4 - RESEARCH-GRADE ORTHOSCOPIC EYEPIECES with Multi-Coated, Parfocal Optics (1-1/4" O.D.) - Acclaimed by amateur and professional astronomers everywhere to be the world's finest eyepieces. These 4-element systems are unsurpassed in resolution, color correction, and flatness of field. Air-to-glass surfaces are 5-layer multi-coated for maximum image contrast and light transmission. 45° field. Precisely parfocal. Barrels are threaded to accept our filters directly. **Focal lengths: 4, 7, 10.5, 16.8, 28mm each...$29.95 ppd. - Set of any 4:...$112.50 ppd. Set of any 4 plus Res. Gr. Erfle 20mm...$137.50 ppd. - Full set of 5 Res. Gr. Orthoscopics plus Res. Gr. Erfle 20mm...$165.00 ppd.** (Sets of 4, 5, or 6 eyepieces are shipped in fitted carrying case (see (27) at no additional charge).
RESEARCH-GRADE ERFLE 20mm (1-1/4" O.D.) - Parfocalized with our Research-Grade Orthoscopics and 5-layer multi-coated. Apparent field in excess of 75° for breathtaking wide-angle observations. Barrel accepts our filters directly. **$36.50 ppd.**

5 - Series 1 KELLNER EYEPIECES (1-1/4" O.D.) - Highly corrected, 3-element design, fully coated. The best in moderately priced eyepieces. Barrels threaded for our filters. **Focal lengths: 6, 12, 25mm each...$12.50 ppd. - 40mm Wide Field...$14.50 ppd.**

6. - KELLNER 40mm EXTRA-WIDE-FIELD (1-1/4" O.D.) - Yields widest field obtainable in 1-1/4" O.D. Enlarged field lens and special field-flattening optics with long eye relief. Barrel accepts our filters... **$22.75 ppd.**

7 - Series 1 ERFLE 20mm (1-1/4" O.D.) - An advanced 5-element system with fully coated, color corrected optics. Wide 65° field. Barrel accepts our filters. **$23.95 ppd.**

8 - ZOOM ORTHOSCOPIC EYEPIECE (1-1/4" O.D.) - Zooms instantly from 8.4mm to 21mm, with excellent image corrections at all powers. Wide 50° field at 8.4mm. Fully coated optics...**$32.95 ppd. - Filter adapter #004**: couples our filters to above eyepiece...**$1.00 ppd.**

9 - ZOOM KELLNER EYEPIECE (.965" O.D.) - Fine 4-element design. Zoom range 7.5mm-22.5mm. Fully coated optics...**$24.95 ppd.**

SUPER-WIDE-FIELD EYEPIECES (2" O.D.) - Premium-quality wide-field eyepieces for 2" focusers. The ultimate in rich-field performance. Fully coated.
10 - ERFLE 32mm (2" O.D.) - Sophisticated 5-element optical system. Wide, flat 65° field...**$67.50 ppd.**
11 - KELLNER 60mm (2" O.D.) - Low power, long eye relief. Ideal for deep-space observations...**$42.50 ppd.**

12 - ERFLE 32mm (1-1/4" O.D.) - As in (10), but with standard 1-1/4" barrel, threaded for our filters. 60° field...**$67.50.**

13 - .965" EYEPIECES - (phone, or request catalog, for details).

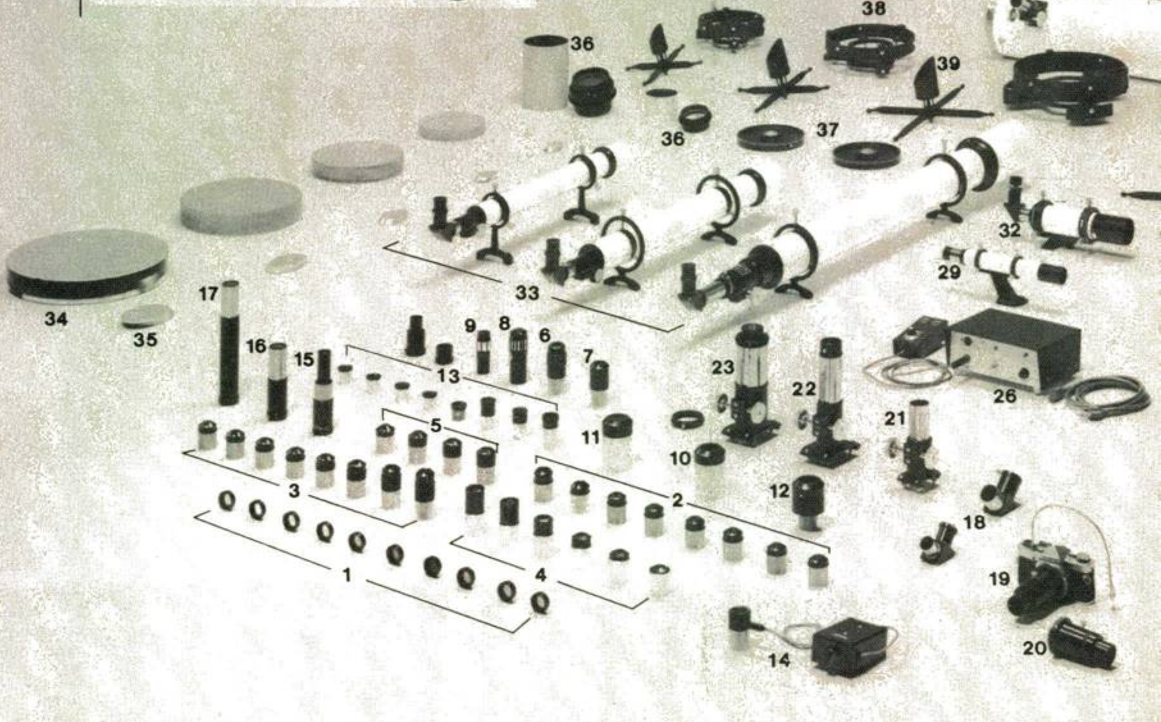
14 - ILLUMINATED RETICLE GUIDING EYEPIECE (1-1/4" or .965" O.D.) - For professional-level photographic guiding. Kellner 12mm optical system, with precisely focusable 4-line glass reticle. Remote brightness control and 3 ft. cable. (Extension cables available) Complete...**$37.50 ppd.**
Micrometer Reticle: Full-field scale for accurate measurements of double star separations, planetary angular diameters, etc. Interchanges with standard 4-line reticle...**$11.95 ppd.**

15 - 2X ACHROMATIC BARLOW LENS (1-1/4" O.D.) - A high resolution, coated, negative achromat with excellent corrections for spherical and chromatic aberrations. **$18.75 ppd.**

16, 17 - 2X AND 3X TELENEGATIVE AMPLIFIERS (1-1/4" O.D.) - The world's finest Barlow lenses. Full 26mm clear aperture, with virtually flawless optical corrections at all photo-visual wavelengths. Produces optimum performance on telescopes of any focal ratio. Fully coated. (16) **2X Model 122...$29.50 ppd.** (17) **3X Model 123...$32.50 ppd. - Combination 2X and 3X Model 124...$39.50 ppd.**

18 - DIAGONAL PRISMS - Quality, right-angle prisms, fully coated. **1-1/4" O.D....$14.95 ppd. - .965" O.D....$10.95 ppd.**

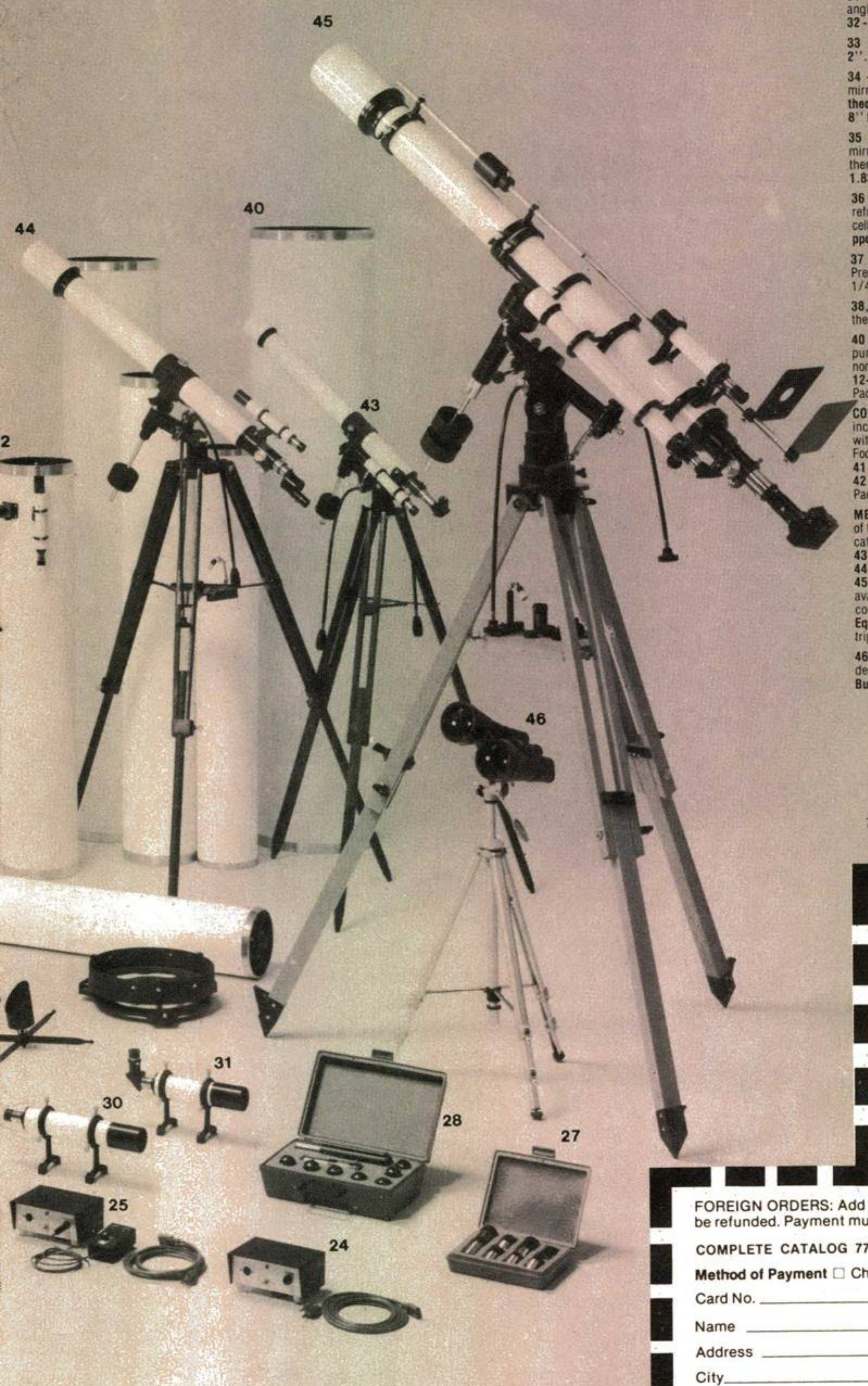
19 - OLYMPUS OM-1 ASTROCAMERA - One of the world's great astrocameras. (Phone or request catalog for details.)...**From $229.50.**



20 - DELUXE CAMERA ADAPTERS - Adapt your camera to telescope focuser instantly. Individually machined from solid bar aluminum. All units permit both eyepiece projection and first (prime) focus photography. Specify either .965'' or 1-1/4'' focuser. (If for Celestron, please specify.) All 1-1/4'' units are threaded for our filters. **Pentax, Praktica, Yashica, Mamiya...$15.95 ppd. - Exakta, Nikon, Canon, Minolta, Miranda, Konica...$23.95 ppd. - Olympus OM-1...$24.95 ppd.**

RACK-AND-PINION FOCUSERS - Precision metal construction. All 3 models include helical-cut rack for ultra-smooth focusing without backlash. Universal bases fit all tube sizes. Standard 1-1/4'' eyepiece holders. **Each focuser is guaranteed to be the finest obtainable in its class.**
21 - Model #67 - Strong, lightweight design for 4'' to 10'' telescopes. 2-3/16'' travel. An excellent value...**$14.75 ppd.**
22 - Model #640 - A heavy-duty deluxe focuser for 6'' to 16'' telescopes. Full 3'' travel for both visual and photographic applications...**$21.75 ppd.**

23 - Model #680 - Our finest focuser. Accepts both 1-1/4'' and 2'' eyepieces. Full 3'' travel for photo or visual observing with 6'' to 16'' telescopes...**$29.95 ppd.**



VARIABLE FREQUENCY DRIVE CORRECTORS - Quality, temperature compensated circuitry for precise electronic guiding. Each model will drive telescopes to 14'' aperture. 20 ft. battery cables, instructions included.
24 - Model #24 - Uses 12v. D.C. Frequency variable between 50-70Hz with knob attached to power box. An excellent value...**$49.50 ppd.**
25 - Model #29 - Uses 12v. D.C. Remote control box with fast-slow buttons and variable center frequency dial for tracking at solar, lunar, or planetary rates...**$62.50 ppd.**
26 - Model #33 - Uses 12v. D.C. or 110v. A.C. Other features identical to Model 29...**$89.50 ppd.**

ACCESSORY CASES - Rugged polyethylene, for dust-free protection of eyepieces, filters, Barlows, etc. For either 1-1/4'' or .965'' accessories. Die-cut foam lining.
27 - Model #51 - 7'' x 8-1/2''...$7.95 ppd.
28 - Model #54 - 8'' x 12''...$10.95 ppd.

VIEWFINDERS - Each with coated, achromatic objective and crosshair eyepiece.
29 - 6 x 30mm: Fine, 4° wide-field finder. Thousands now in use. 2-ring bracket included...**$14.75 ppd.**
30 - 7 x 50 mm: Large 50mm aperture. Sharp, brilliant images. (Not for use with prism.)... **$24.75 ppd. - Brackets: $7.95/pr.**
31 - 7 x 50mm Right-Angle: 50mm aperture, for both straight-through and right-angle viewing. Prism included...**$29.95 ppd. - Brackets: $7.95/Pr.**
32 - 7 x 50mm Right-Angle: As above, but with bracket for Celestron 8... **$42.50 ppd.**

33 - PHOTO-GUIDE TELESCOPES - (Phone or request catalog for details.) **2''...$39.50 - 2.4''...$65.00 - 3.1''...$138.00**

34 - PARABOLIC PRIMARY MIRRORS - Professional quality hand figured Pyrex mirrors, aluminized and quartz overcoated. **Each mirror is guaranteed to reach all theoretical limits of performance. 6'' f/8...$49.95 ppd. - 10'' f/6...$134.95 ppd. 8'' f/6 or f/7.5...$79.95 ppd. - 12-1/2'' f/6...$239.95 ppd.**

35 - ELLIPTICAL SECONDARIES - For optimum performance with any primary mirrors. Aluminized, overcoated. As optically flat as master opticians can make them. Minor axis sizes shown, postpaid: **1.30''...$8.00 - 1.52''...$11.50 - 1.83''...$13.50 - 2.14''...$16.50 - 2.60''...$19.50.**

36 - OBJECTIVE LENSES - As used in Meade guide telescopes and equatorial refractors. Air-spaced, achromatic, fully coated. Mounted in machined, threaded cells. Dewcap and dustcap included. **2'' f/12... $19.50 ppd. - 2.4'' f/15... $34.50 ppd. - 3.1'' f/15...$74.50 ppd.**

37 - SETTING CIRCLES - Die-cast aluminum, 6'' diameter. Machine engraved. Precision guaranteed. Standard 1-1/2'' bore:...**$35.00/pr.** Other bores (from 1/4'' to 2''): **add $1.50 per circle.**

38, 39 - MIRROR CELLS AND SPIDERS/DIAGONAL HOLDERS are available to fit the tubing below. Phone, or request catalog, for details.

40 - FIBERLITE TELESCOPE TUBES - 20% more rigid, yet 40% lighter, than pure fiberglass, with low thermal conductivity. Polished end rings available at nominal cost. Partial price list: **7'' I.D. x 50''...$36.00 - 9-1/4'' I.D. x 60''... $49.50 12-3/8'' I.D. x 62''... $68.00 - 12-3/8'' I.D. x 72''...$76.00**
Packing charge on tubes...**$4.00.**

COMPLETE OPTICAL TUBE ASSEMBLIES - Fully Assembled. Each assembly includes the premium quality Meade components described above: Fiberlite tube with end rings, primary mirror and cell, spider and secondary mirror, Model #67 Focuser, 6 x 30mm viewfinder. Shipping charges collect.
41 - 6'' f/8 tube assembly...$144.95
42 - 8'' f/6 tube assembly...$189.95
Packing charge on tube assemblies...**$4.00**

MEADE EQUATORIAL REFRACTORS - Whether beginning or serious amateur, one of these superb instruments will fit your observing requirements. Phone or request catalog for details.
43 - Model #291: 2.4'' Equatorial Refractor...$195.00
44 - Model #300: 3.1'' Equatorial Refractor...$325.00
45 - Models #420 - #440: 4'' Equatorial and Photo-Equatorial Refractors, available with guide telescope, illuminated reticle eyepiece, motor drive, frequency corrector, astrocamera. **From $1175.00**
Equatorial Mounts - Each includes complete mount, circles, 2 cables, hardwood tripod. **Mount for Model #291...$95.00 - Mount for Model #300...$157.00**

46 - 20 x 80mm ASTRONOMICAL BINOCULARS - Coated optics. Magnificent for deep-space observing...**$127.50 ppd.**
Bushnell Tripod: fully adjustable...**$49.50 ppd.**

MEADE INSTRUMENTS
721 West 16th Street, Costa Mesa, Calif. 92627 • (714) 646-9281

MAIL ORDERS: Circle numbers for items desired and write your specific requirements on a separate sheet—or use the order form which accompanies our catalog.

1 2 3 4 5 6 7 8 9 10 11 12
13 14 15 16 17 18 19 20 21 22 23 24
25 26 27 28 29 30 31 32 33 34 35
36 37 38 39 40 41 42 43 44 45 46

PAYMENT: Personal or bank check, money order, or credit card (BankAmericard or Master Charge)

TELEPHONE ORDERS: accepted with payment either COD or credit card (we do not accept collect calls).

SHIPMENT: All orders are processed for shipment within 24 hours of receipt.

FOREIGN ORDERS: Add 20% to cover Air Parcel Post charges—any excess will be refunded. Payment must be made by bank check in $ U.S.

COMPLETE CATALOG 77-C — $1.00 (Catalog free with any order)

Method of Payment ☐ Check or Money Order ☐ BankAmericard ☐ Master Charge

Card No. ______________________ Expiration Date / /

Name ______________________

Address ______________________

City______________ State__________ Zip__________

MEADE INSTRUMENTS
721 West 16th Street, Costa Mesa, Calif. 92627 • (714) 646-9281

GAZER'S GAZETTE

Observing the Outermost Planets

by
Henry J. Phillips

Anyone whose hobby involves collecting things can tell you all about the craving for completeness that accompanies his avocation. If a person owns all but one item in his collection, the frustration he feels until he gets that last article is much greater than it was when he owned only half of them. Many astronomy enthusiasts are as familiar with this desire for completion as any stamp collector — witness the observer who spends long hours of anxious search in the effort to locate those last few Messier objects.

Perhaps the most obvious collection is that of the nine planets of the solar system. We live on one of them, of course, so that takes care of the first; five of the others are brighter than most of the stars and are easily spotted in the twilight or night sky. But three of Earth's solar system siblings are faint, slow moving, and demand a closer search of the heavens. These three planets are the three most distant: Uranus, Neptune and Pluto.

Uranus can just barely be seen with the naked eye — and even so, you have to know exactly where to look in a very clear, dark sky if you want to see it without optical aid. Neptune and Pluto require the use of a telescope (quite a large telescope for Pluto); if no bright guide stars are near, finding them can be a problem.

So why bother looking for these three planets? As we've already hinted, you'll get a wonderful feeling of satisfaction from having observed all the members of our sun's family. This feeling may manifest itself as a quiet sense of fulfillment, or perhaps as a long boasting session to your jealous friends. Searching for and finding Uranus, Neptune and Pluto can be a lot of fun, and will certainly be good practice for locating other celestial objects of similar magnitude.

For the past decade or so, spring and early summer have been the best times for observing these three planets. During this period, all three have been more or less on the same side of the sun (although they're by no means lined up) as the points they have reached in their orbits happen to coincide. Because they're distant, they poke along in their orbits and spend several years in the same general area of the sky.

Let's take a look at Uranus, Neptune and Pluto individually and find out just what we can expect to see — or not see — on these three bodies.

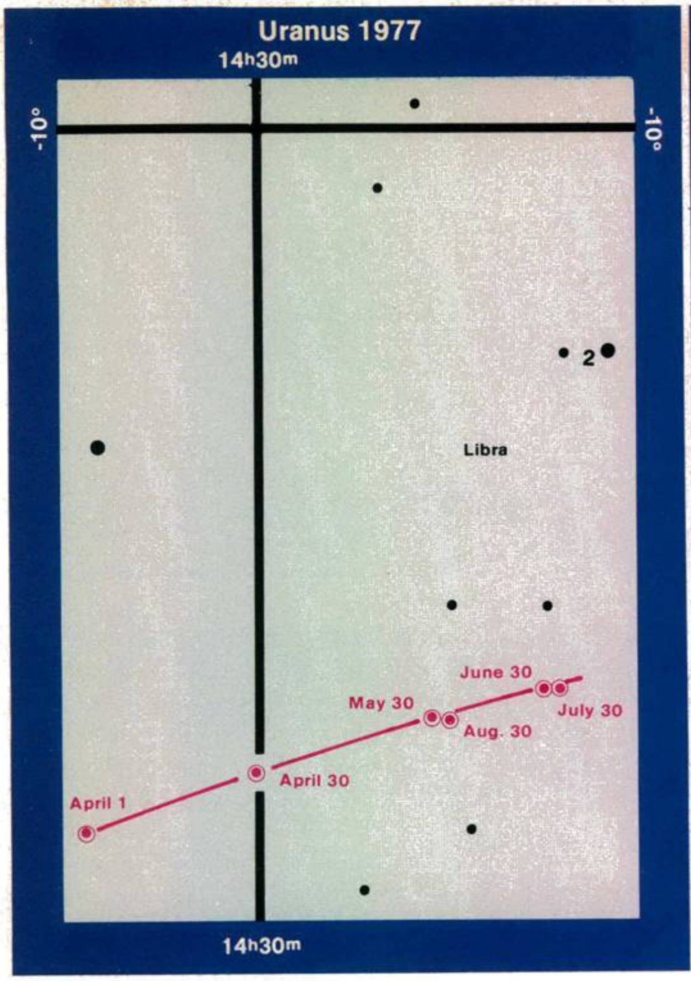
Uranus

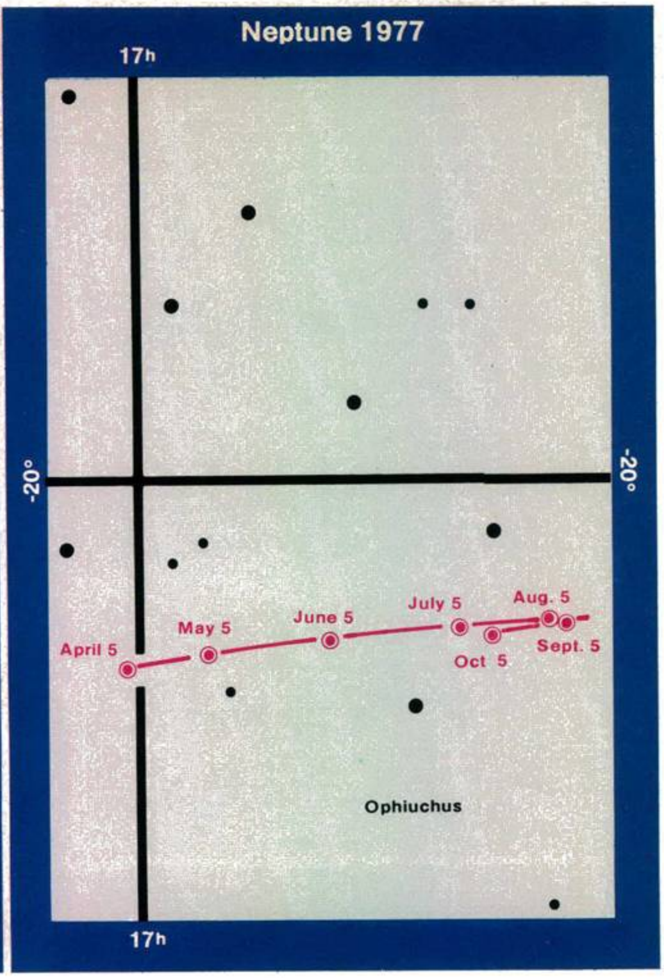
We can get a good indication of just how distant the outer planets are when we realize that Uranus, the nearest of the three, is farther from Saturn than Saturn is from the sun! Uranus' mean distance from the sun is about 1,780 million miles (2,870 million kilometers), and it takes 84 years to complete one orbit — almost three times as long as Saturn takes. Between one opposition and the next, Uranus moves about 4-1/2 degrees along the ecliptic; even at this crawling pace, it's the swiftest of the outermost planets.

Uranus shines at magnitude 5.7, so technically it's bright enough to be seen with the naked eye. Observers who have so seen the planet are extremely rare, however, so don't try too hard. If you want to catch a glimpse of Uranus without optical aid, you won't be able to see more than a very faint point of light. In the event that you do succeed at this project, you can consider yourself among the eagle-eyed.

For those who prefer an easier task, binoculars will help quite a bit; Uranus becomes easily visible even with a pair of opera glasses. With a reasonably good star chart in front of you, you can't miss picking out the planet from the background stars.

For telescope users, Uranus presents a featureless green disk 3.9 seconds of arc in diameter. In





past decades, some observers have reported seeing a wide equatorial belt similar to Saturn's, but no such feature appears in the best telescopes today, and the planet's limb darkening may have produced the illusion of a belt. In the telescope, Uranus' distinct green color is a fine sight and unique in the heavens.

This year, Uranus is at opposition on April 30 and is located a few degrees west of third magnitude Alpha Librae. It's brighter than any of the stars in its area, so it should be a fairly simple matter to find it. Sweep along the ecliptic between Alpha Librae and Lambda Virginis (just across the Libra border), and you can't miss Uranus. If you need help, consult the map on this page.

Because of its incredibly high equatorial tilt (98 degrees!), Uranus exhibits different parts of its surface to Earth at different times. In the early 1960s, the equatorial regions of the planet were in view; by 1985, we will see the planet pole-on.

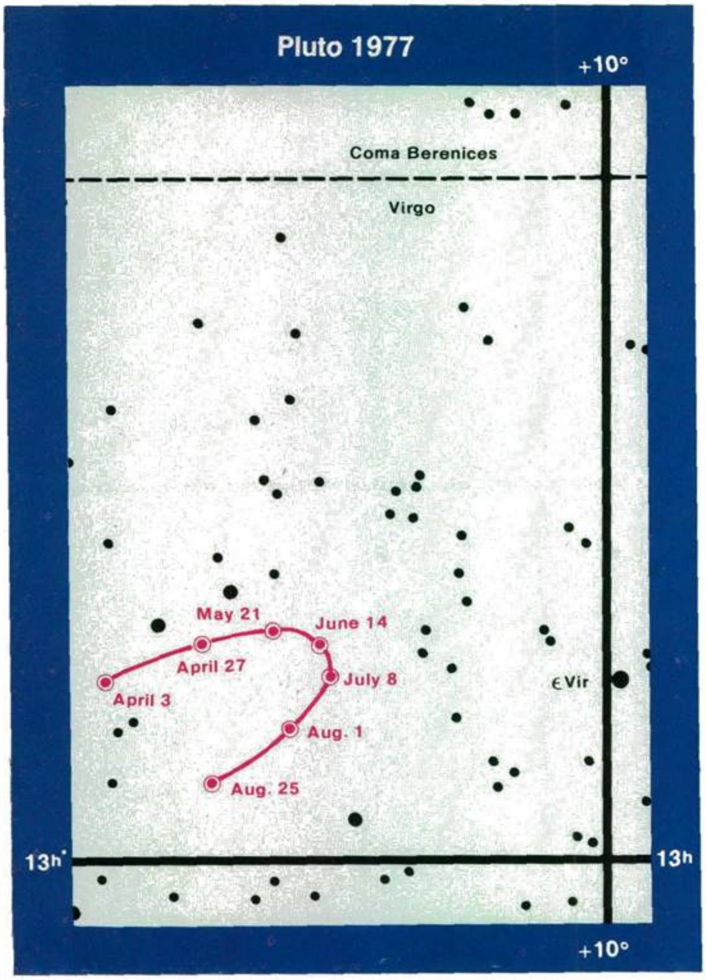
Larger telescopes will not produce any visible detail on Uranus' disk, but they will reveal some of Uranus' five moons. Titania and Oberon — the two largest and farthest from Uranus — were discovered by Sir William Herschel shortly after he found the planet itself. Both are 14th magnitude, and they're within reach of a 10 inch instrument. Ariel and Umbriel are slightly smaller and dimmer, and the planet's glare may drown them out unless you can block out the disk. The fifth moon, Miranda, has only been detected photographically.

Neptune

Although it's about the same size as Uranus, Neptune is much more distant from Earth and therefore much fainter and harder to spot. You'll need at least a two inch telescope for Neptune because its magnitude is only 7.7. The planet's average distance from the sun is about 2,800 million miles (4,500 million kilometers), and it takes almost 165 years to make one trip around the sun. Neptune has yet to complete one orbit since its 1846 discovery!

Something to remember when observing all the outer planets, including Neptune, is their retrograde motion. The outer planets appear to travel backward along their paths at times because they move more slowly than Earth; as Earth speeds along its orbit, it gradually catches up, passes, and leaves the slower moving planets behind. The result of this "catch-up" game is an apparent backward motion; the outermost planets spend longer times moving retrograde than their inner neighbors. Neptune, for example, moves retrograde this year from March 18 to Aug. 25 — more than five months. It reaches opposition on June 5, when it will be located in the constellation Ophiuchus.

There are no bright guide stars anywhere along



Neptune's 1977 path; perhaps the best way to find it is to start with first magnitude Antares in neighboring Scorpius, move north five degrees to fourth magnitude Omega Ophiuchi, and move east about an equal amount. You'll then be close to Neptune's position, and you should be able to find it with the help of the map on page 43. Through the telescope, Neptune is even more of a disappointment than Uranus. Its disk is only 2.5 seconds of arc in diameter and, of course, it shows no surface features at all. Neptune is not as highly colored as Uranus, but its blue-green hue is unmistakable.

Neptune's largest moon, Triton, is a 14th magnitude object and should be visible in a 10 inch telescope. It revolves around Neptune in 5 hours 21 minutes in a highly elliptical orbit; its apparent distance from the planet varies between 8 and 17 seconds of arc. Neptune's second satellite, Nereid, has (again) only been seen on photographs.

Pluto

When you know what you're looking for and what you can expect to see, Uranus and Neptune are no longer difficult objects; once seen, you'll be able to locate them again — even a year later, at their next oppositions. Pluto is different. Pluto is *always* hard to find, under all circumstances. Imagine trying to locate Titania, Oberon or Triton without having the planets to which these moons belong nearby. That's how hard it is to find Pluto, for the planet is only as bright as these satellites (14th magnitude).

Recent studies have shown that Pluto, rather than Mercury, deserves the title of "the smallest planet". With a probable diameter of only about 2,000 miles (3,170 kilometers), Pluto is smaller than our own moon. At its distance on the April 2 opposition date — 2,748 million miles (4,421 million kilometers) — Pluto's apparent diameter is less than 1/4 of one second of arc, and anyone who still expects to see surface detail hasn't been paying attention.

Even so, Pluto is easier to see these years because it's nearing perihelion (the point in its orbit at which it lies nearest to the sun) in 1989. Pluto is about two magnitudes brighter now than it will be at aphelion in 2113, so present day would-be observers of Pluto should consider themselves fortunate. What's the reason for this difference in brightness? The answer lies in Pluto's orbit, which has an eccentricity of 25 percent — meaning that Pluto is almost two billion miles more distant from the sun at aphelion than perihelion. In addition, Pluto's orbit is tipped to the ecliptic plane by about 17 degrees, which explains its distance from the ecliptic. This year it lies in northern Virgo, near the border of Coma Berenices. Many years from now, at aphelion, Pluto will lie far south of the ecliptic on the other side of the sky.

Without a detailed star chart and a large telescope (eight inches or more), you can't hope to find Pluto; the map on this page only indicates its relative position.

Whatever size instrument you have, your best bet for locating Pluto is photography. Take photos at least a week apart and use as long an exposure as you can — the longer the better. Good photos will show the tiny speck of light that is Pluto shifting its position against the background stars. It's a good idea to take more than one photo per night to insure distinguishing Pluto from defects or clumps of grain in the film.

Uranus and Neptune can be photographed in the same way, but these planets are a lot easier to capture on film. You can record the image of Uranus in a full sized constellation shot, using a 50mm lens. You don't even have to guide if you don't want to, as a 20 second exposure can pick up the planet. (Guiding, of course, will help make the planet brighter during longer exposures.) Neptune, being fainter, will need 10 to 20 minutes of guided exposure for its image to appear.

Once you've successfully seen or photographed the three outer planets and are the proud viewer of all the major bodies of the solar system, what's left to do? You can rest on your laurels if you like, but it's definitely more rewarding to go out and try it again! Uranus, Neptune and Pluto are always available for another look — and who knows? Maybe you'll find them more easily next time.

Cosmology...supernovae and Seyfert galaxies...the latest in astrophysics...radio astronomy...man's views of the universe from earliest times until now...

sooner or later everything you want to know in the natural world reveals its secrets to members of the

Natural Science Book Club

Fred Hoyle
Astronomy and Cosmology
A MODERN COURSE
Frontiers of Astrophysics
Man Discovers the Galaxies
palmer and fowler
Fieldbook of Natural History
BLACK HOLES QUASARS, THE UNIVERSE
ENCYCLOPEDIA OF ASTRONOMY AND SPACE
The Secret Life of Animals

Take any 3 books, (values to $56.90) for only 99¢ each

if you will join now for a trial period and agree to take 3 more books—at handsome discounts—over the next 12 months.

65220. ODDITIES OF THE MINERAL WORLD. *William B. Sanborn.* Handsomely illustrated, knowledgeable guide that spotlights some of the more peculiar and unusual mineral formations. **$9.95**

61710. THE MEDIEVAL MACHINE. *Jean Gempel.* An enlightening look at the times, the men, the conditions and the remarkable inventions of the Middle Ages. Many illustrations. **$12.95**

73240. QUASARS, PULSARS, AND BLACK HOLES. *Frederic Golden.* A thorough review of the spectacular discoveries in astronomy, as told by the science editor of *Time* magazine. 24 color photographs. **$7.95**

36645. THE BOOK OF SHARKS. *Written and illustrated by Richard Ellis.* A magnificently illustrated, carefully researched and complete natural history. Covers all major types, with explanations of their biology and behavior. *Counts as 2 of your 3 books.* **$25.00**

77615. THE SECRET LIVES OF FISHES. *Bernard Gordon.* The life stories—and not in the least what you expect them to be—of more than 70 of the world's most intriguing fishes. Big, 6″ x 9″ volume, handsomely illustrated. **$12.95**

49340. FUNDAMENTAL ASTRONOMY: Solar System and Beyond. *Franklyn W. Cole.* Traces our intellectual assault on the mysteries of the universe from man's earliest sensory-oriented glimmerings to the very frontiers of modern astronomical thought. **$16.50**

59800. MAN DISCOVERS THE GALAXIES. *Richard E. Berendzen, Richard C. Hart and Daniel Seeley.* The history-making discoveries by the band often great astronomers who led the way between 1915 and 1940, are recaptured through original letters, photographs and archival treasures. **$15.95**

49267. FRONTIERS OF ASTROPHYSICS. *Edited by Eugene Avrett.* A compilation by 12 distinguished scientists containing the most up-to-date data on the latest developments in astrophysics, from solar research and stellar evolution, to neutron stars, supernovae and intergalactic matter. **$20.00**

36395. BLACK HOLES, QUASARS AND THE UNIVERSE. *Henry L. Shipman.* An absorbing exploration of the frontiers of astronomy. **$12.95**

36512. THE BOG PEOPLE/THE MOUND PEOPLE. *P.V. Glob.* Perfectly preserved 2,000-year-old bodies buried in peat bogs, all murdered...6-ft-long oak coffins hidden within mounds of earth...two ancient mysteries solved by an eminent archaeologist. *Set counts as 2 of your 3 books.* **$25.00**

55000. THE ILLUSTRATED ENCYCLOPEDIA OF ASTRONOMY AND SPACE. *Ian Ridpath, Consultant Editor.* This one-volume encyclopedia covers the full range of astronomical knowledge and space exploration, from ancient times to the present. **$16.95**

73337. THE RAPE OF THE NILE. *Brian Fagan.* The plundering of ancient Egypt's treasures and the rise of Egyptology. Illustrated. **$14.95**

73530. THE REBIRTH OF COSMOLOGY. *Jacques Merleau-Ponty and Bruno Morando.* Story of the Greek, classical, and astrophysical ages of the study of the origin and structure of the universe. **$12.50**

48705. FORECASTS FAMINES AND FREEZES. *John Gribbin.* Explores some fascinating questions about the earth's future, the greenhouse effect, a new ice age and shifting magnetic poles. **$8.95**

MEMBERSHIP BENEFITS • In addition to getting three books for 99¢ each when you join, you keep saving substantially on the books you buy. • If you continue your membership past the trial period, you will be eligible for our Bonus Book Plan—an important way to save even more, at least 70% off publishers' prices. • Your Book Club News, describing the coming Main Selection and Alternate Selections, will be sent to you 15 times a year at three to four week intervals. • If you wish to purchase the Main Selection, do nothing and it will be sent to you automatically. • If you prefer one of the Alternates or no book at all, simply indicate your decision on the reply form always enclosed with the News and mail it so we receive it by the date specified. • The News is mailed in time to allow you at least 10 days to decide if you want the coming Main Selection. If because of late mail delivery of the News, you should ever receive a Main Selection without having had the 10 day consideration period, that Selection may be returned at Club expense.

(Publishers' prices shown)

77620. THE SECRET LIFE OF ANIMALS. *Lorus and Margery Milne and Franklin Russell.* Lavishly illustrated account of the dramatic discoveries recently made about the behavior of animals. Over 300 full-color photographs. *Counts as 2 of your 3 books.* **$29.95**

85090. THE UNIVERSE. *Lloyd Motz.* Examines the origin, evolution, and future of the universe. **$15.00**

48470. FIELDBOOK OF NATURAL HISTORY. *E. Laurence Palmer and H. Seymour Fowler.* The most authoritative and comprehensive guide to natural history available. With the aid of over 2,000 illustrations, it explores all major plant and animal species as well as rocks and minerals, the earth, moon, sun, and planets, and space exploration. **$19.95**

50610. THE GREAT INTERNATIONAL DISASTER BOOK. *James Cornell.* All of the spectacular catastrophes from the eruption of Vesuvius in A. D. 79 to the Guatemala earthquake of 1976. **$12.50.**

55375. INFRARED: The New Astronomy. *David R. Allen.* The first comprehensive account of the last decade's remarkable breakthroughs in infrared astronomy. **$12.00**

69311. PLAGUES AND PEOPLES. *William H. McNeill.* A fresh, groundbreaking study of the history of infectious disease and its effect on civilizations, past and present. **$9.95**

34670. ASTRONOMY AND COSMOLOGY. *Fred Hoyle.* A peerless survey of the ideas, principles and processes of astronomy by one of the world's outstanding astronomer-cosmologists. Outsized volume, over 700 pages, 617 illustrations and 45 charts. **$16.50**

52650. THE HERITAGE OF COPERNICUS. *Edited by Jerzy Neyman.* Commemorates the 500th birthday of Copernicus by offering 25 highly readable essays on the quasi-Copernican revolutions that have occurred in the past five centuries. *Counts as 2 of your 3 books.* **$30.00**

68735. PHYSICS OF THE EARTH AND PLANETS. *Alan H. Cook.* "A well-written volume on the application of basic physics to the study of the earth and planets."—Choice. *Counts as 2 of your 3 books.* **$24.75**

Natural Science Book Club 4-8AK
Riverside, New Jersey 08075

Please accept my application for membership and send me the three volumes indicated, billing me only 99¢ each. I agree to purchase at least three additional Selections or Alternates during the first 12 months I am a member, under the club plan described in this ad. Savings range up to 30% and occasionally even more. My membership is cancelable any time after I buy these three books. A shipping and handling charge is added to all shipments.

3 books for 99¢ each.
Indicate by number the 3 books you want.

☐ ☐ ☐

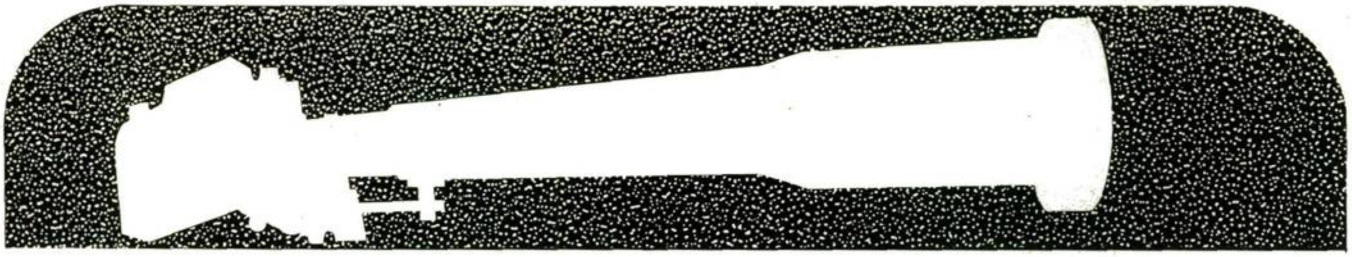
A few expensive books (noted in book descriptions) count as 2 choices.

Name ____________

Address ____________

City ________ State ______ Zip ______

(Offer good in Continental U.S. and Canada only. Prices slightly higher in Canada.)



PHOTOGRAPHY IN ASTRONOMY

Printing Your Astrophotographs

Part 3: Nebulae

by

Richard Berry

The major observatories have vast stock collections of fantastic pictures that show objects shining white against a jet black background. Why then — since the sky is the same for both you and the research astronomer — do the faint features of galaxies and nebulae stand out so well when the observatories photograph them, and so poorly so often with your precision small astrophotography rig? Of course, the big telescopes are bigger, but how does that make them better — or does it?

The answer emerges when you realize that big telescopes give bigger images. If you take a picture with your eight inch f/5 reflector (focal length 40 inches), and an astronomer at Lick Observatory takes a picture with the 120 inch f/5 reflector (focal length 600 inches) of the same object, on the same film, on the same night, on the same mountain, his image will be 15 times bigger than yours. That's where the quality comes in, of course, because the bigger image contains more exposed film grains, and the longer focal length means more detail. But if the big telescope is used to photograph a galaxy 15 times more distant (assuming it's the same size), then the images from the big and small telescopes should contain the same amount of detail and number of film grains, and (so you would think) ought to be equally stunning!

In fact, they should be — but often they aren't.

Since many observatories employ a professional photographer or darkroom technician whose job it is to obtain the best possible results from the astronomer's glass plates, it's not surprising that you see excellent pictures taken by large telescopes. The difference between a stunning photograph and a dull snapshot often lies in a few routine photographic techniques and tricks that anyone can do at home, but which are seldom used outside the observatory. The tricks are simple things: Using a high contrast paper to add "snap" or simply copying a finished print and making a print from the copy negative may bring out faint details that weren't obvious before.

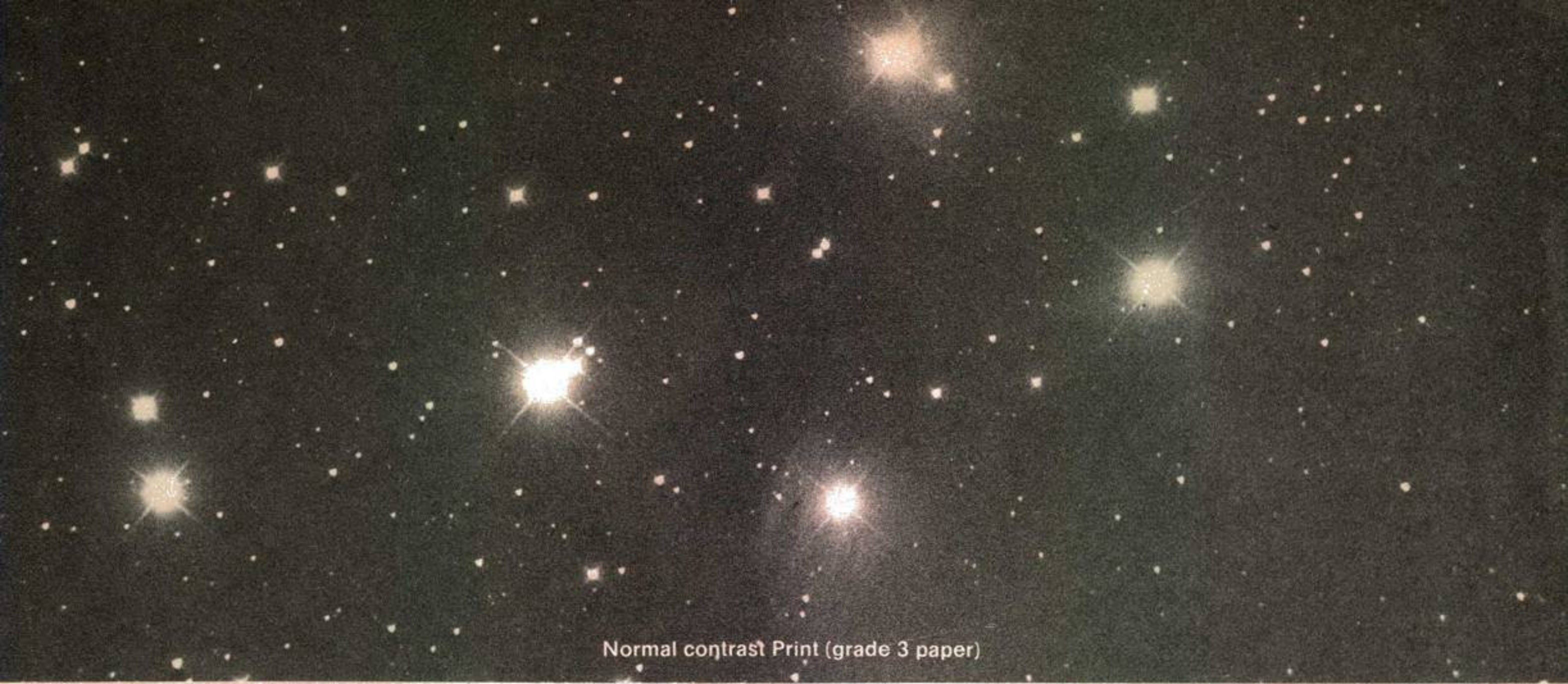
Sometimes contrast is gained without intending it. Before making hundreds of prints for public distribution, most observatories make a copy negative so the valuable original negative won't be damaged. The copy often looks better than the original because it's snappier. But before you see it, it may be printed in a book: The cameraman at the printing plant may add his own snap to it; then a slightly over-inked pressman may blacken the background still more! Often the process goes too far. Subtle details are lost, hard edges appear where none truly exist, and the picture becomes harsh or garish. High contrast is thus a dangerous process, for as well as enhancing the subtle detail in the original, it may destroy and distort the appearance of the real object in the sky.

In the end, you'll have to judge the total quality of your own astrophotograph, and then apply the printing technique that displays it best without falsifying its appearance. You may find, in fact, that the simplest technique — a straight print on medium contrast paper — gives the best result.

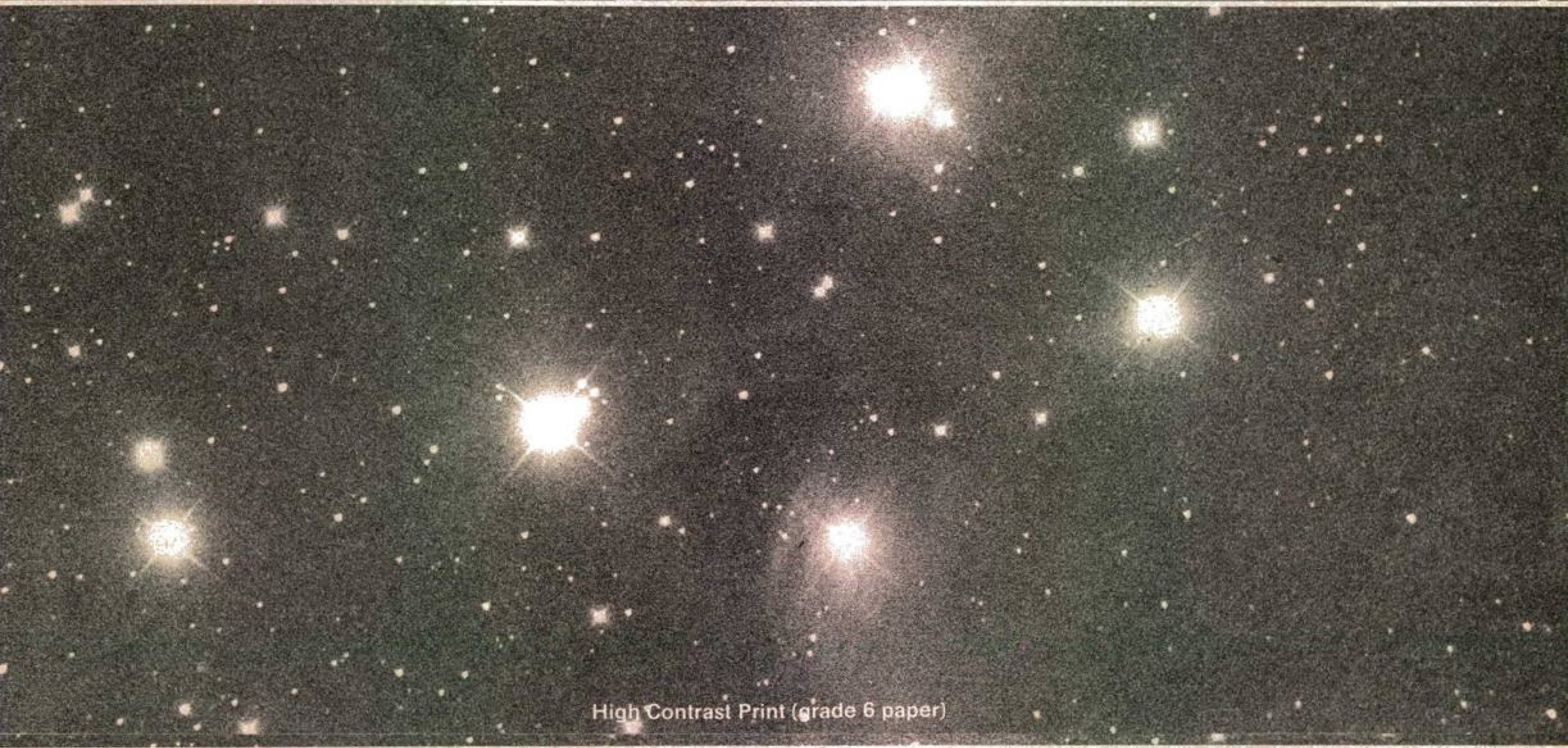
The Normal Contrast Print

Start your attempt to obtain the best possible print from any negative with a print on normal or medium contrast paper. Normal contrast paper almost always gives the best looking results with high contrast Kodak spectroscopic films such as 103aO, 103aE, or 103aF if they are exposed from a

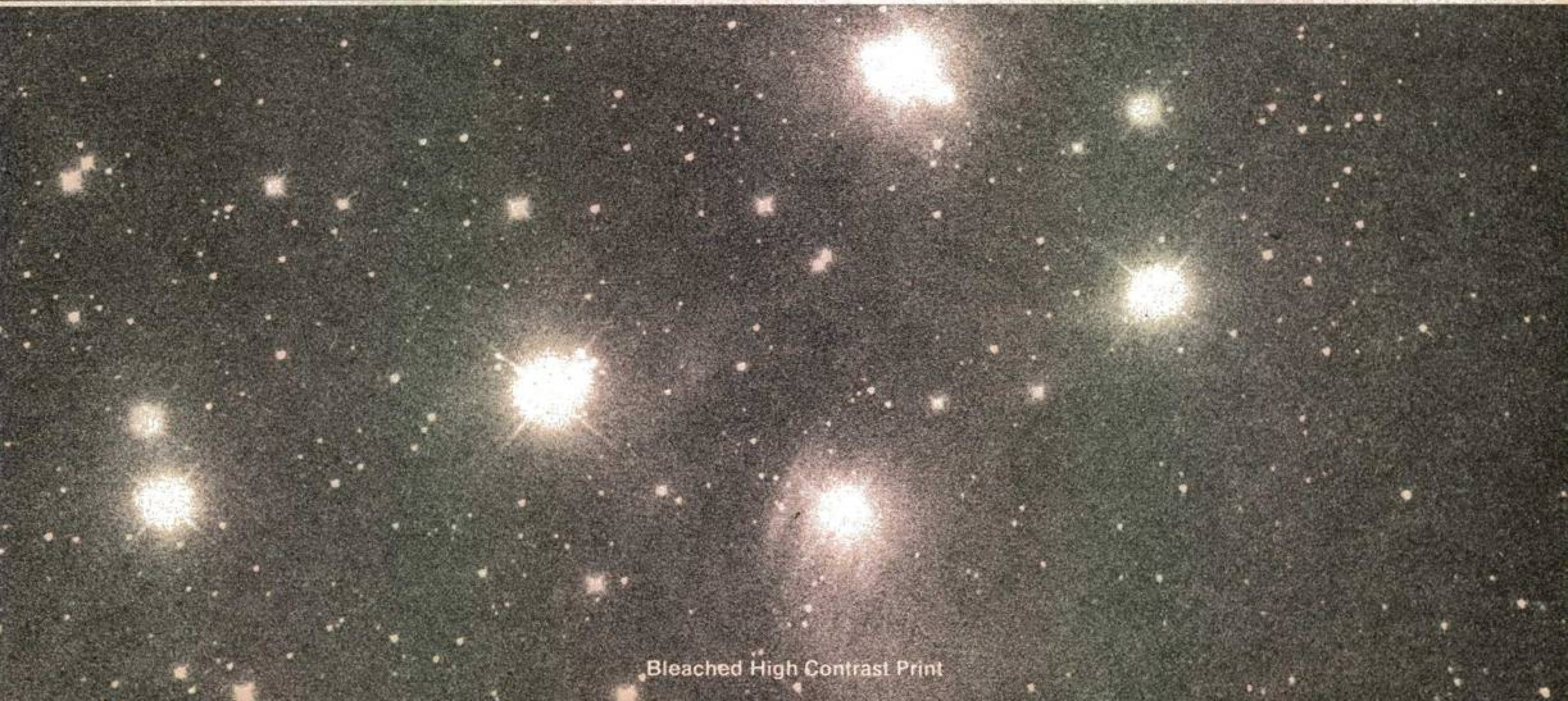
Top: Normal paper shows a full tonal range but barely shows the faint nebulosity surrounding the Pleiades stars, especially Merope (lower middle star). Middle: Brovira grade 6 is the highest contrast paper on the amateur photographic market. A print on this paper often brings out details that are nearly invisible on normal contrast papers. Bottom: By bleaching a slightly dark print, more details can be separated from the sky background. Photograph by Tom Renner and John Harmon.



Normal contrast Print (grade 3 paper)



High Contrast Print (grade 6 paper)



Bleached High Contrast Print

About the Pictures in This Article

The pictures in this article were all made from one negative taken by Tom Renner and John Harmon using a 10 inch f/6 homemade telescope at the Newtonian focus. The 20 minute exposure on GAF 500 black and white film was developed in D-76 developer for 15 minutes at 68 degrees Fahrenheit (20 degrees Centigrade). For the purposes of this article, the negative is ideal: well-guided, sharply focused, taken on a moderate grain, medium contrast film that has been push processed and exposed from a site that is only moderately free of light pollution. In short, the picture was made under the same conditions many of our readers have to work with, on a commonly available snapshot film.

Applying these techniques to a single not-too-good negative allows you to see what each technique can do; if we had used pictures sent in by our readers, you'd only see a collection of good pictures. However, to the many readers who have written to us about their techniques and methods in astrophotography, ASTRONOMY extends its thanks.

site free of light pollution. Normal contrast paper does not accentuate the negative's graininess, as high contrast processes do, and normal contrast papers come closest to reproducing the full range of brightness seen in the object.

In making a good print, remember that a deep sky astrophotograph should not have a perfectly black background sky; the best results come when a deep gray sky is used. (For a comparison series, see Photography in Astronomy, December 1976.) Care should be taken not to underdevelop your prints; make sure you agitate the print in the developer for the full recommended time. Less time results in loss of quality and "muddy" tones.

The Straight High Contrast Print

The next logical recourse is to make a print on the highest contrast paper you can find. Agfa (a German company) makes a grade 6 paper in their Brovira line. This is the highest contrast paper readily available. You can use Kodak's or Ilford's grade 5 papers with an extra strong developer bath to gain a nearly equivalent contrast, but if you use the Brovira paper in strong developer, you can gain more contrast from it too.

You'll find that the printing exposure is very critical with high contrast papers. For example, a 20 second exposure may give a perfect print, but 22 and 18 second exposures would be completely unacceptable. Furthermore, if your enlarger doesn't illuminate the negative with perfect uniformity, one side of the picture could print too dark, while the other side prints too light. If this happens, follow the manufacturer's instructions to adjust it for even illumination.

Usually pictures taken on the spectroscopic emulsions are very crisp on high contrast paper, and no longer show the full range of detail on the negative. Bright nebulae tend to show "burned out" whites. Grain is strongly accentuated compared to lower contrast prints, but is usually still acceptable.

If you take astrophotographs on ordinary films like Tri-X or HP-4, high contrast papers will probably give the best looking results you'll get. The paper will bring out the full range of values present in the negative, with burning out of the brighter areas.

You can lose the advantage of high contrast paper by making your prints too dark — even just a little too dark! The best background tone is a salt and pepper gray-black that shows the grain of the film very well. Anything darker than that obscures nebulae and faint brightness fluctuations.

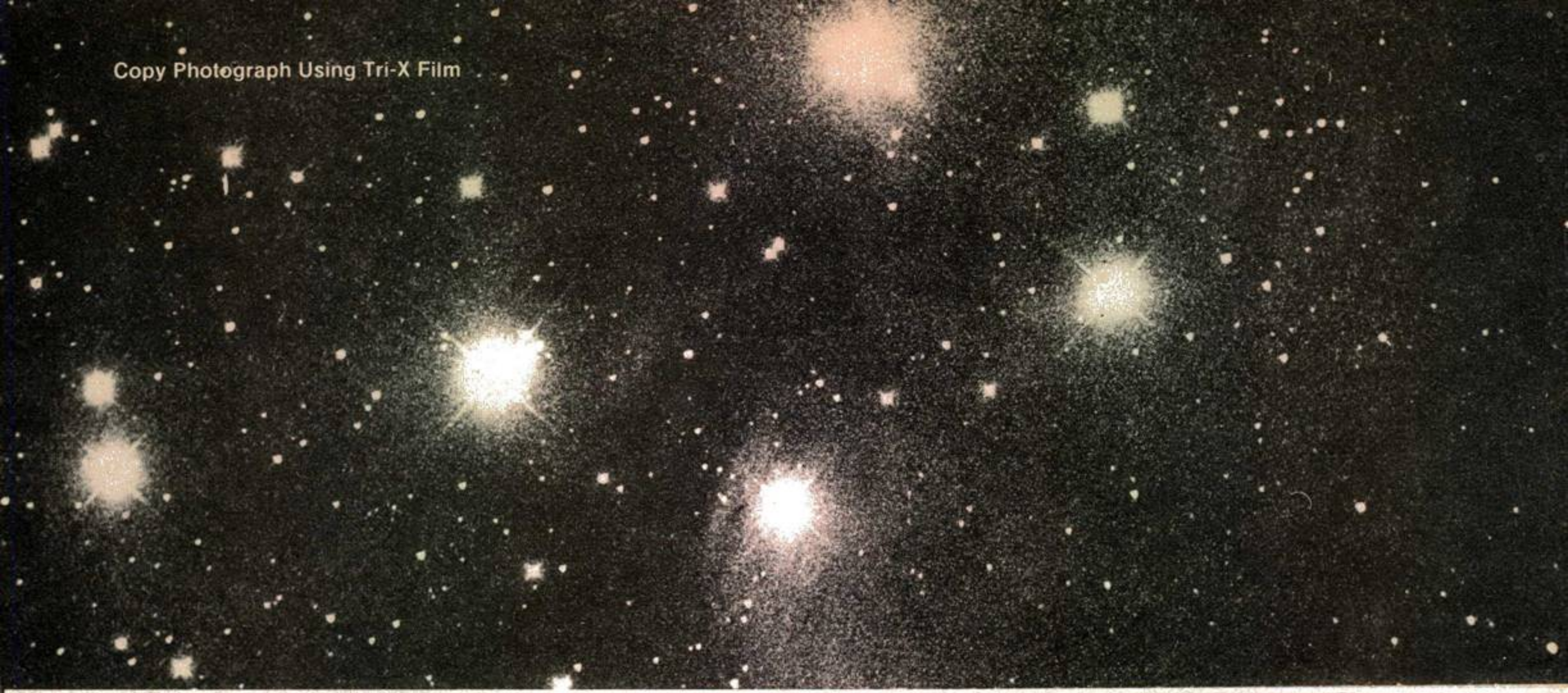
Bleaching for Contrast

If you bleach a print (that is, if you remove silver from it uniformly), the light areas (which contain little silver) will become lighter more quickly than the dark areas (which contain a lot of silver) — thus increasing the tonal separation between the nebula and the sky. Bleaching is a powerful process that can give amazing results, especially if you want clean white highlight tones.

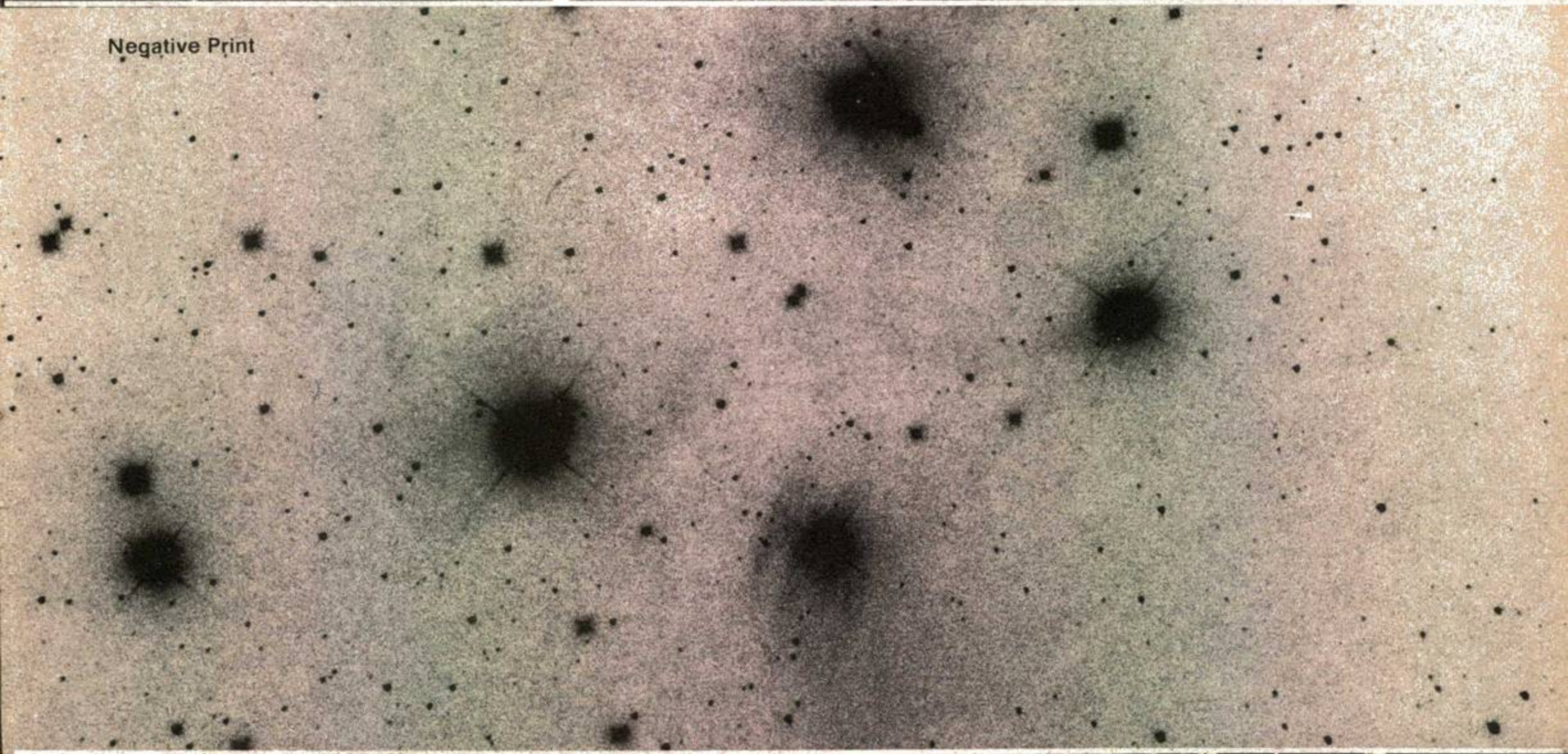
Bleaching is easy to do in the darkroom. You'll need one extra print tray and some potassium ferricyanide crystals, which you can buy at a photographic supply store. Work as follows: Mix a tiny amount of potassium ferricyanide (about 1/8 teaspoon) into a quart of water. Place this solution in your extra tray after you finish your normal printing session. To bleach a print, place it in the hypo bath for a minute; then lift it out, drain it, and place it in the bleach solution (with vigorous agitation) for 10 seconds. Lift it out, drain it, and put it back in the hypo for a minute. You may have to repeat the process a dozen times to get the optimum bleaching, but this prevents overbleaching which ruins the print. Fix thoroughly after bleaching and then wash and dry normally.

As you bleach, you'll first notice light gray areas turning white, and then darker areas slowly lightening. You should start with a slightly dark print and plan to bleach it until the background tone reaches the optimum salt and pepper gray tone. Bleaching takes some experimenting before you can get it right every time, but it often gives a striking

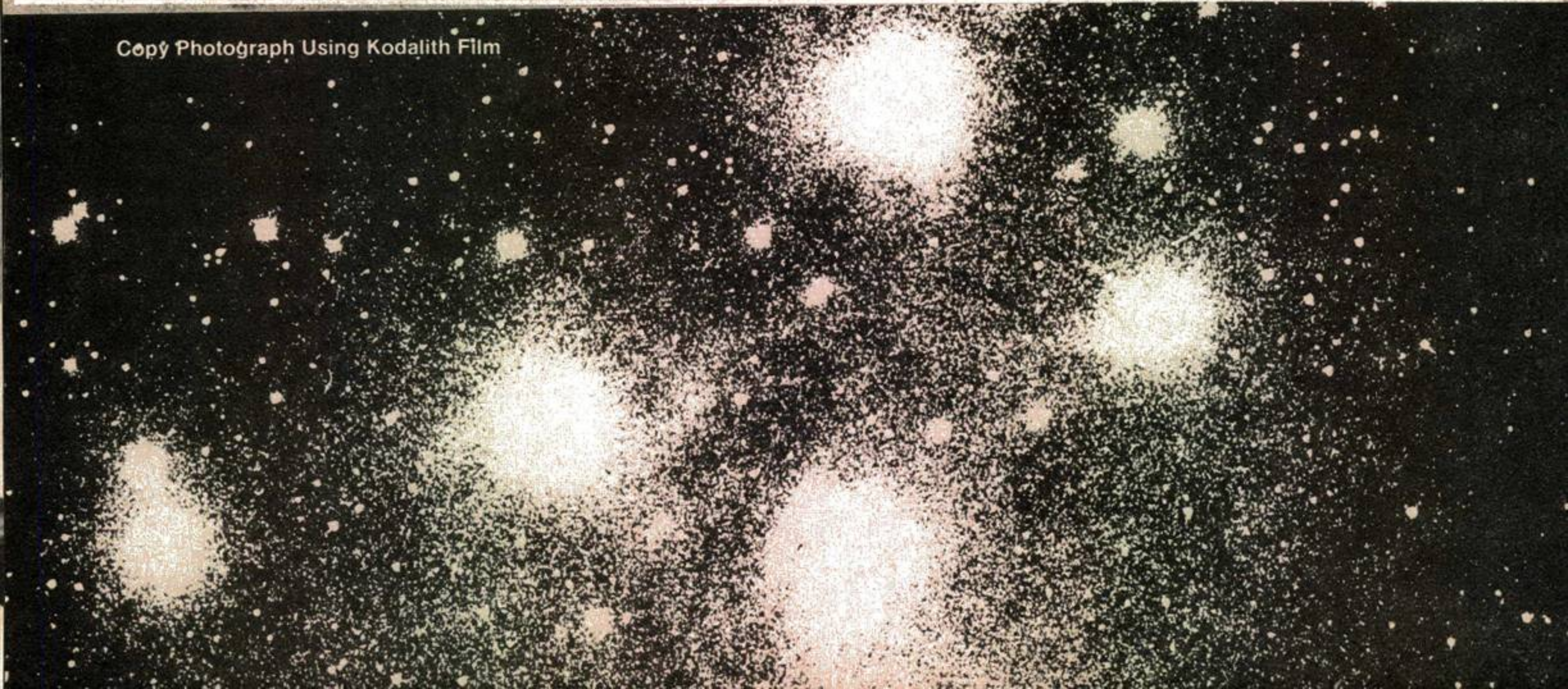
Top: Add more "snap" to pictures by rephotographing them. This print was copied on Tri-X film, and then printed on grade 6 paper. Middle: A negative print sometimes shows features difficult to see on a positive. An 8 x 10 inch positive was made on Kodak Fine-Grain Positive film; shown here is a contact print made on grade 6 paper. Bottom: Kodalith film was used for this print to drop all middle tones; the image contains only black and white. Photograph by Tom Renner and John Harmon.



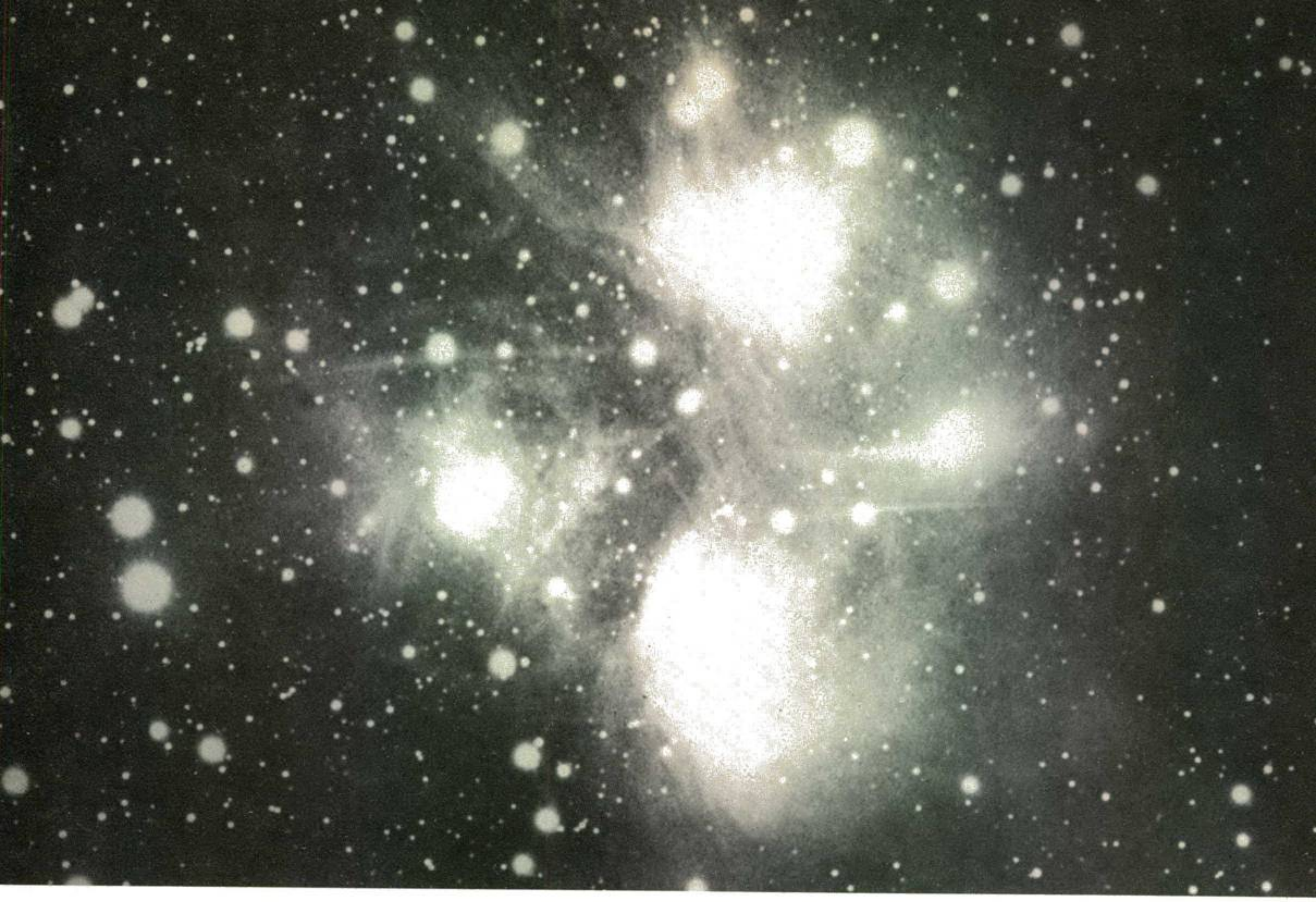
Copy Photograph Using Tri-X Film



Negative Print



Copy Photograph Using Kodalith Film



How much of the detail brought out by high contrast techniques is really there? For comparison, above is a photograph by Edward E. Barnard taken with a powerful astrographic camera that shows the Pleiades nebulosity much better than the negative used in this article. Compare each feature — wisp for wisp — and you'll see that much of the enhanced detail is real. Barnard enhanced his contrast by rephotographing a positive transparency. Yerkes Observatory photograph.

improvement in faint or near-threshold nebular details.

Negative Prints

Astronomers seldom examine positive prints of astronomical objects; they prefer to examine the negative directly. You may find you'd like to see negative prints too, mainly because a faint smudge of nebula is easier to see against a light background than against a dark sky background. Negative prints are traditionally used in scientific journals because they are less easily harmed by poor printing quality. Finally, negative prints make handy "instant star maps".

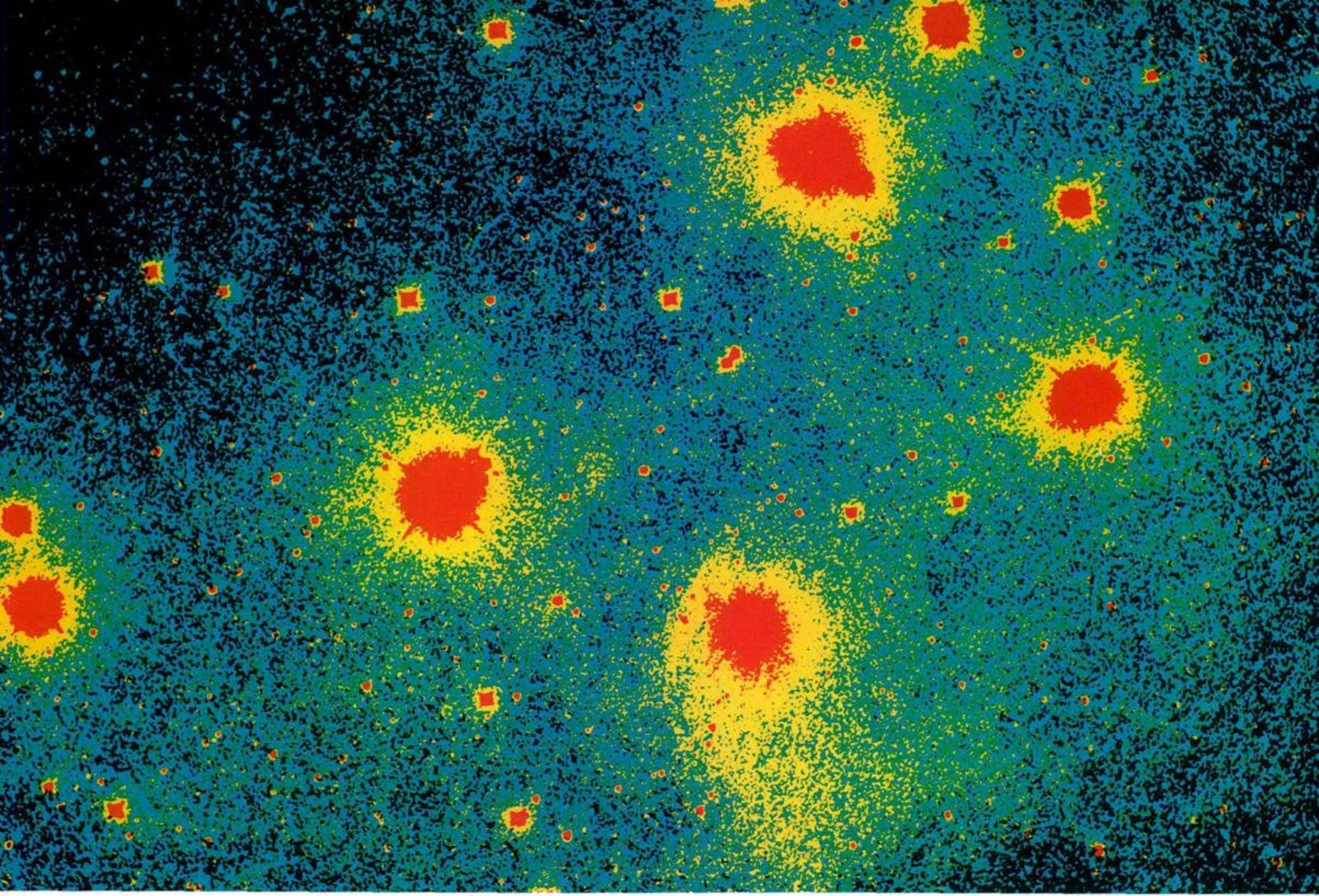
The best way to make a negative print is to make an enlarged positive film, and then make a contact print from that film to give you the negative image. The best readily obtainable material for making the enlarged positive is Kodak's Fine Grain Positive Sheet Film #7302, which is available in 4x5, 5x7, 8x10 and 11x14 sizes. This film is much like a print paper emulsion coated on transparent plastic. It can be handled under ordinary safelights, and it's developed and fixed in the same chemicals that paper is. Use it just like printing paper to make a medium contrast transparency as big as you want your final negative print to be.

You can make negative contact prints on any contrast grade paper, or to any image tone you want, just as you can make enlargements. For instance, make your negative print very light for a striking star map or make it medium gray in tone on grade 6 paper for a print that shows maximum detail in nebulosity.

Copying for Contrast

Another method widely used for enhancing details that are difficult to see in the original print is to recopy the original. Nothing tricky is involved. Simply rephotograph the original print on any black and white film, and then make a print on normal or high contrast paper. You'll have to take great care that no reflections or wrinkles in the surface of the original are recorded and masquerade as nebulae or the spiral arm of a galaxy! The original print should be carefully spotted free of dust and other defects, and then mounted on cardboard for the best freedom from reflections.

Copying need not yield only positives. If you copy with a slide film, the slide can be placed in your enlarger to make a negative print. Since slide films are generally rather contrasty, they're a good



Bright color outlines nebular details in a posterized color print. The image is made from four Kodalith prints of different darknesses rephotographed in sequence through color filters on color film. In a picture made this way, color is entirely arbitrary; for instance, the sky could be made red and the stars black. Many images returned from space are processed in this way to squeeze maximum information from them. Photograph by Tom Renner and John Harmon.

copy material for negative prints, though not as good as the full size negative method. Copy prints are never as sharp as the originals, but they do allow you to make copies from a single good print.

Graphic Arts Materials

A specialized class of films called Graphic Arts Films have a contrast index that is virtually infinite; they will render any scene in just two tones — black and white. You can use these films to push nebula detection to the ultimate limit, because with them you can render a tiny, almost invisible darkening on the original negative as a black to white tone change on the final print. Such pictures usually have very little esthetic quality — they look harsh or washed out — and can be grossly distorting if you aren't cautious in using them and in interpreting the effects they produce. Nevertheless, they are useful for distinguishing the outermost limits of faint nebulae recorded on the negative. However, they also bring out vignetting effects, emphasize dust and processing defects in the negative, and many show nonexistent features resulting from scattered light in your telescope or enlarger.

You can buy Graphic Arts films in 35mm rolls 100 feet long (Kodalith Ortho Film #6556, Type 3), or in 4x5, 5x7, 8x10 and larger sheet film sizes, and you'll need a special developer for use with them. Information is available from Kodak and the photographic magazines. In general, exhaust all other possibilities first before turning to Kodalith materials for astrophotographic prints, not only because they are tricky to use, but also because they don't give very pretty results. You may find that grain becomes all-important at ultrahigh contrast, or that image defects totally swamp any useful gain in the image contrast.

Graphic Arts films can also be used to produce "posterized" effects — translating black and white images into color coded images that show vivid features of the nebula or galaxy. The posterization process has been described in various photographic magazines and books; interested readers may seek information in them.

Limits to Contrast Enhancement

We all recognize that we can't get something for nothing. How, then, can we get so much more from an astrophotograph than drugstore processing usually offers? What limits are applicable? Why can't we go on getting more and more out of a picture forever?

ASTROPHOTOGRAPHY TIPS

How Much to Enlarge

Print size greatly affects the proper selection of paper contrast. The more you enlarge the image, the higher the contrast grade of paper needed to maintain the same *apparent* level of contrast that you would see in a smaller image. If you want real "snap" in your prints, don't overenlarge; keep them small and they'll look better. An inch diameter (25mm) disk is enough for Jupiter; a half inch (12mm) is sufficient for Mars and Saturn. Enlargements of five to eight times should be the rule for deep sky subjects unless the print is intended for special display.

You'll find the same contrast grade paper has a lower visual contrast for large prints than it has for small prints. Therefore, in making big enlargements, you may want to use a higher contrast paper. But increasing paper contrast with print size is tricky when using grainy high speed films, as high contrast papers exaggerate the grain to the point where it can become overwhelming. High contrast papers will help you show the most stars and nebulosity in your deep sky photos. But be careful that your big enlargements show more than just grain.

One of the best uses for burning and dodging is to control the exaggeration of limb darkening in planetary photos. Many astrophotographers never realize that up to 1/4 Jupiter's disk may often be lost in the blackness of exaggerated limb darkening. Duplicating the sharp edged disk seen through the telescope is a three step operation. First, make an overall exposure of the planetary disk and background — about 1/2 the time required to make a normal print with jet black background. Second, use the dodging wand to shadow the disk of the planet while burning-in the background to dark black. Finally, use the sheet of cardboard with the small hole to burn-in the planetary detail without overexposing the limb. These three steps essentially produce a "ring" of lightly exposed area at the planetary limb which allows underexposed details in the negative to appear in the final print. Be sure to mention such burning and dodging in the notes on the back of each astrophoto.

Spotting should only be used on small dust and lint squiggles — not on the long white streaks that indicate a scratch on the negative base. These thin white lines, usually parallel to the long dimension of the negative, should have been eliminated before printing. You can usually see these scratches as thin dark lines when the negative is held up to the light. To eliminate them, apply a very thin film of grease to that area of the film base (not the emulsion!) using a clean fingertip touched to the tip of your nose or to the surface of a jar of petroleum jelly. (Be careful not to overdo this!) Next, wipe the excess grease off with a piece of surgical cotton. The grease will find the scratch, causing it to disappear. Commercial greases are also sold in photo stores for this purpose.

Photo Records

Have you ever looked through your old astrophotos and found yourself fumbling to recall when and how some unidentified shot was made? Every photo that you plan to keep, either on display or in a file, should have full identifying information on it. As a minimum, the following information should be noted on the reverse side of each print: object, date, equipment, f-ratio, filter, film, exposure and developer. For any photo submitted to a magazine, also include your name and address, where photo was taken, seeing conditions, notes about any special processing, and the type of enlarging paper.

Never write notes on the back of a photo with a ballpoint pen or pencil; it will almost surely show through. Felt tipped pens work nicely on regular enlarging papers but smear on RC materials. One solution is to use white adhesive labels or one of the felt tipped "transparency marking" pens available at office supply stores. Adding these notes to each print may seem a bother, but as your memory dims, you'll be glad you did.

New Films Available

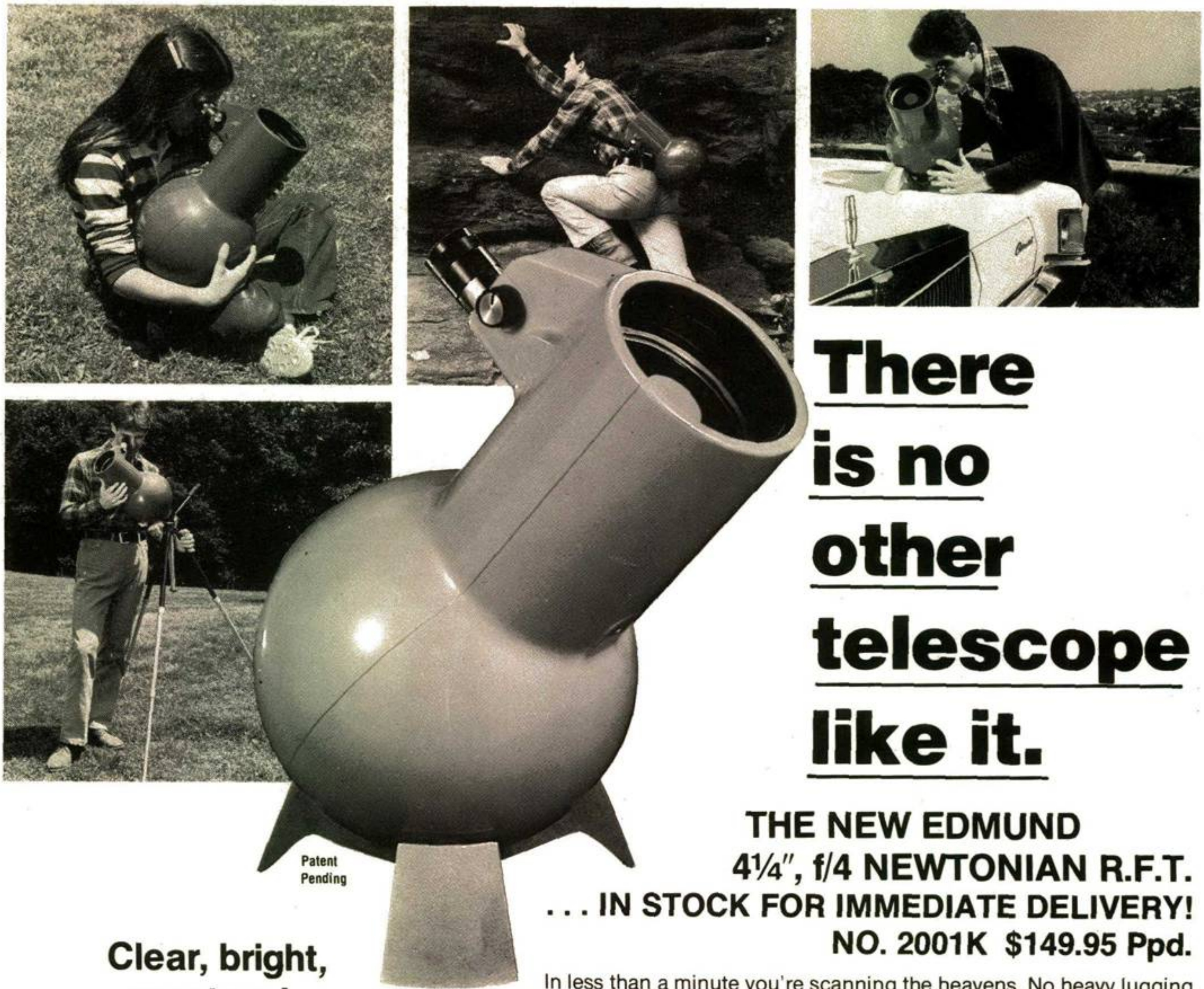
Kodak has recently introduced four new color films and will soon be introducing more. Two of them — Ektachrome 64 and Ektachrome 200 — will be of interest to astrophotographers. We invite our readers to let us know how these new films perform for astrophotography.

The first question is easy to answer: Standard photographic processes don't give the best *display* to the image on the negative. By using high contrast methods, you can put the astronomical image in a tone scale extending from pale gray to dark gray, making it visible. Normal drugstore prints merely leave the tone scale stuck between gray and just-a-bit-different gray.

But the limitations to image enhancement are fundamental: There is only a certain amount of *information* in the image, and no amount of squeezing can extract more. Each exposed grain in the image represents some number of photons of light reaching the film. Since the number of grains involved is finite (that is, there is a large, but countable, number), the amount of information the film can possibly contain about the universe is finite. Hence, once we reach the "best display limit", we can't go further.

Images obtained by the giant observatory telescopes have a larger number of exposed film grains, so more information is contained in the image. The fundamental reason why the big telescopes bring more information about distant galaxies is that more information is present in their images. In a thoroughly practical sense, we can see why fine grain film (which has more but smaller film grains) delivers better performance than grainy film (with few but larger grains). Of course, we use grainy films because they are faster, and on a chillly night, a short exposure is better!

Squeezing the most from your negative is a good occupation for cloudy nights. Remember one more basic trick: You can't see grain as well in a small print! Although you can make your basic high contrast print 8x10 or larger, when you contrast-copy, make the copy print smaller — about 4x5. It'll look sharper and less grainy, and will have a better tonal scale than it would if you made it 8x10. Remember also that superhigh contrast is a special technique that won't help your moon and planet photographs much at all. And even for low contrast deep sky objects, you should apply such powerful techniques with care and moderation.



Patent Pending

There is no other telescope like it.

THE NEW EDMUND 4¼", f/4 NEWTONIAN R.F.T.

. . . IN STOCK FOR IMMEDIATE DELIVERY!

NO. 2001K $149.95 Ppd.

Clear, bright, spectacular wide angle views of stars, moon, comets . . . instant set up . . . portable!

In less than a minute you're scanning the heavens. No heavy lugging out and in. No complicated set up, no involved collimation. Just pop in the eyepiece, focus, and its 3½° field of view gives you more stars in a single view than any other type of telescope. Bright, crisp, finely resolved images, plus ease of use and portability, make this beauty an ideal scope for every skygazer. It's probably the easiest to use telescope ever . . . over your shoulder, in your lap, on a tripod. Or just rotate the spherical base on its own mount for use on a table, car hood. Take it anywhere (only 17", 10 lb.). Top quality optical system: 4¼", f/4 parabolic primary mirror (⅛ wave, 17" F.L.); prealigned ⅛ wave diagonal on a coated optical window seals optics from moisture and dust; std. 28mm Kellner eyepiece (gives 15X, higher with other eyepiece or Barlow). Fast posi-grip roller focusing (25' to infinity). Bright Scharfanian red (doesn't impair night vision) with adjustable carry strap. A precisely *engineered,* quality instrument at a great price (with no hidden crating charges). A second scope "must". *There is no other telescope like it.*

Edmund Engineers for You

GIANT FREE CATALOG

NEW 164 Pages. Over 4,500 Unusual Bargains for Hobbyists, Schools, Industry
JUST CHECK COUPON!

EDMUND SCIENTIFIC CO.

300 EDSCORP BUILDING • Barrington, N.J. 08007
America's Greatest Science • Optics • Hobby Mart
(609) 547-3488

COMPLETE AND MAIL COUPON NOW

EDMUND SCIENTIFIC CO. 300 Edscorp Building, Barrington, N.J. 08007

☐ SEND FREE 164 PG. CATALOG "K"

Send me:
____ unique Edmund Telescope(s)
#2001K priced @ $149.95 ea. $ ______

Charge my ☐ American Express
☐ BankAmericard
☐ Master Charge

Service & Handling Charge $ 1.00
Enclosed is ☐ Check ☐ M.O.
For TOTAL of $ ______

Interbank No. ______
Card No. ______
Expiration Date ______

Signature ______
Name ______
(Please Print)
Address ______
City ______
State ______ Zip ______

30-DAY MONEY-BACK GUARANTEE. *You must be satisfied or return any purchase in 30 days for full refund.*

EQUIPMENT ATLAS

continued from page 39

force the still-warm pitch to conform to the curve of the mirror. If the pitch hardens before you can do so, immerse lap and mirror in warm water (about 100 degrees Fahrenheit) for a couple minutes, remove and continue as often as needed.

After the pitch lap and mirror are in relatively good contact, you must cut channels in the lap so that the pitch can flow during polishing. Trim off the overhanging edges of the lap with a sharp razor blade. Measure for the exact center of the lap and indicate it with a light watercolor pen. Take your pitch lap mat, painted heavily with the thick mixture of cerium oxide, soap and water, and place it so that the center of the lap is in one of the corners of an open square. *Do not* center it exactly in a facet, or where two channels would meet. If this is done, the mirror will polish out in rings.

Put a sheet of clear plastic wrap over this and then place your mirror atop this "sandwich", curved face down. Put a heavy weight on top of the mirror (a counterweight from an older instrument, some very heavy books, or even rocks in a bucket will work well). Immerse the tool in a pan of hot water up to the level of the pitch itself. As the pitch softens, the lap will permit the mat to sink into it, creating channels in its surface, and then will reach the curved surface of the mirror. This is called hot pressing. The plastic wrap will prevent the pitch from sticking to the glass of the mirror, but will permit good contact. Renew the hot water as needed until contact is assured.

Another method used is to employ a hacksaw, lubricated with the polishing agent-soap-water mixture to cut the channels. Chipping of the facets is almost inevitable and may lead to problems later. Try the rubber lap technique first — it's much easier.

After you see contact through the mirror, carefully slide off the mirror, remove the plastic wrap by peeling it free of the pitch and then, starting in one corner, work the mat free of the lap. Do this slowly, under water, to avoid chipping many facets. (A few small chips won't matter). If localized, use some melted pitch to fill in any gaps in the area, and then cold press the mirror by placing the cerium oxide or rouge coated mirror blank in the just-as-heavily-charged pitch lap, taping the edges to seal in moisture, and then placing about one pound of weight on the sandwich. Leave it in this position for at least two to three hours to insure good contact. You may have trouble making a good pitch lap, so don't be discouraged. You will find everybody has a way of making a pitch lap that's perfect for him, but which won't work for you. Don't worry though — try again!

Polishing

When the mirror and lap are in contact, you can begin to polish. A mixture of cerium oxide and water (one tablespoon to one pint of water) on the facets of the lap is the usual amount of polisher. Place the mirror on top and polish, using a 1/3 "W" stroke. Go very slowly; the speed of the strokes should be one every three to five seconds with moderate pressure. In the first 30 to 60 minutes of polishing, the mirror will stick and skid, but as soon as contact improves as you work the mirror and lap together, polishing will set into a pleasant routine. Stick to the 1/3 "W" stroke — be sure the overhang is never more than one inch over the edge of the lap — and remember to keep turning the mirror while walking around the grinding stand and turning the tool.

Polish for at least 1-1/2 hours, renewing the polishing mixture every 15 minutes by adding an eyedropperful of well mixed solution to either side of the lap. If you have good contact between mirror and pitch lap, the center of the mirror will begin to be transparent from the polishing action of the lap. In really good laps, the mirror may appear to polish all over and seem to be semipolished.

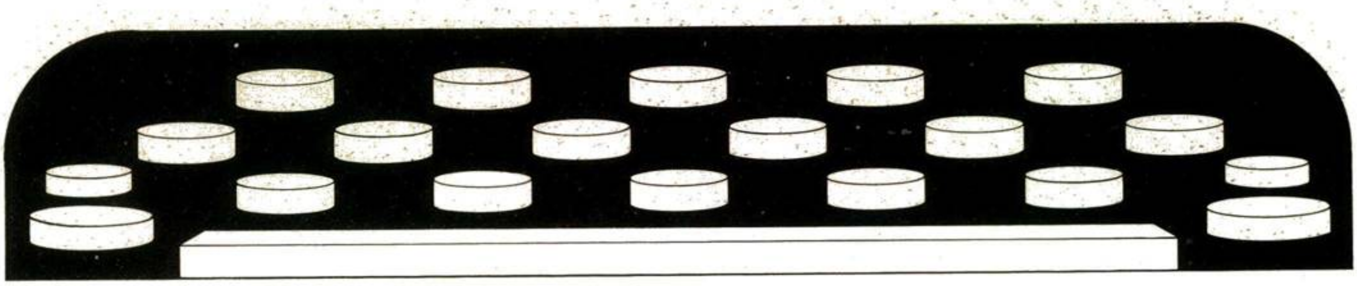
When you get too tired to continue polishing, wrap the mirror and tool (with lots of polishing mixture betwen them) in a clean plastic bag to keep them from drying out. If you go off and leave the mirror unworked for a month, they will dry out and stick tightly together, so schedule your working hours every day or evening in sessions at least an hour and preferably two or three hours long.

How long does polishing take? It varies — from six to eight hours total time to about 24 hours, depending on exactly what mixture of speed, pressure, polishing agent, and personal charm you bring to this enjoyable chore. In any case, your goal is to get a fully polished mirror *before* you worry about the next part — figuring the optical surface.

Before each polishing session, recoat the polisher with the water solution, put the mirror on top, and then add a five pound weight to cold press the pitch into conforming to the mirror surface. Start off slowly until the mirror and lap are working together — you'll get to know the feel of good contact — and then keep up a slow but steady pace. You can amuse yourself by watching the bubbles move around the pitch facets or listening to good music as you work.

After a while you may find the pitch facets oozing together under the forces of polishing. You'll have to trim the facets back (to keep the channels in the lap open) with a single edged razor blade. Be sure to rinse any little scraps of pitch away when you finish trimming; then cold press for 30 minutes or so before you polish again.

Alan Witzgall works as an optomechanical technician for Keuffel and Esser. He obtained his bachelors degree in earth sciences (astrogeology) at Kings College. He has ground 12 telescope mirrors from 4-1/4 inches to 12 inches, and is currently working on his 13th — a 10 inch Newtonian. Witzgall is head of the mirror grinding workshop operated by the Cranford (N.J.) Amateur Astronomers, Inc.



IN FOCUS

Sir / Perhaps it is an error in my own perception, but the December 1976 cover description claims to show us "... from a place just the other side of the LMC — our own spiral galaxy and, somewhat to its side, the Small Magellanic Cloud." The text of the cover story claims that the SMC is *farther* from us than the LMC. The picture on page 9 appears to show both the LMC and the SMC, so they must both be in the same direction from us. How then can we go "just beyond" the closest one to us, look back, and see our point of origin *and* the *farthest* one from our point of origin. Is this "artistic liberty" — or am I misinterpreting the facts?

DAN WEST
Corona, Calif.

Mr. West / No, we did not take artistic liberty with the Magellanic Clouds; we took an extremely wide-angle view. The position taken is slightly behind the Tarantula nebula in the LMC — behind considerable amounts of dust and gas — and we assumed that the Tarantula is on the backside of the LMC. The SMC lies only approximately in the same direction as the LMC, separated by more than 20 degrees in the sky — so that from the LMC, the galaxy and the SMC are roughly 90 degrees apart in the sky! To insure accuracy in the perspective in the painting, we built a scale model of the galaxy and the Magellanic Clouds, and photographed it with a wide-angle camera lens. Thus, even the correct foreshortening effect appears in the galaxy's spiral arms. The painting on pages 12 and 13 of the January issue is also a panoramic view spanning about 120 degrees.

Sir / I very much enjoyed your article "The Messier Catalog: Taking A Second Look" in the December 1976 issue and have some additional information on the subject. Kenneth Glyn Jones adds NGC-205 (the second companion to M-31) as M-110 in his book, **Messier's Nebulae and Star Clusters**, since it was probably observed and drawn by Messier in 1773. This well-known object is excellent with averted vision and fully deserves to enter the ranks of the Messier objects.

M-91 has been convincingly identified as NGC-4548. A magnitude brighter than NGC-4571 (the previously assumed M-91), it is visible in a 4-1/4 inch telescope.

Besides the French Revolution, another possible reason for Messier's not revising his catalog was William Herschel. In 1781, Messier made his last published observation for his list; in 1784 the final Messier catalog was published. In the interim, stirred by Messier's work, Herschel — using vastly superior instruments — observed 500 objects and soon brought his totals into the thousands. In the face of such steep competition, it is no wonder that Messier abandoned the field to a greater power.

I am intrigued by your list of "notable omissions" from Messier's list. I think it would be interesting to compile a list of the "best non-Messier objects". I nominate the Perseus double cluster, Coma Berenices, the open cluster NGC-2244 (coincident with the Rosette nebula), the galaxies NGC-253 and NGC-4565 (the latter, very elongated "Spindle galaxy" is near Coma Berenices), and the planetary nebula NGC-7009 (the Saturn nebula).

BILL LARSON
Minneapolis, Minn.

Mr. Larson / The identification of NGC-205 as M-110 has not taken popular hold. Messier definitely included it in a drawing he prepared of M-31, so there is just as much reason to include it in the Messier list as the other "additional" objects. Jones' book was a primary source during research for the article, and is highly recommended.

What other clusters, nebulae or galaxies would observers like to include in a list of the best "non-Messier" objects? Drop us a line and let us know which are your favorites!

Sir / I read with great interest your article "Observing Saturn" (ASTRONOMY, February 1977). While your statement that Encke's division cannot be glimpsed with any aperture less than 10 inches is generally true, it is not absolutely true. On a midwinter night in 1974-75, I was able to see the division clearly in my eight inch Celestron. It was one of those rare nights of "perfect" seeing, probably found on only two or three nights of any given year and lasting but a matter of hours. Also the ring system was wide open at the time. A W56 green filter enhanced it greatly.

It was one of those rare experiences that an amateur waits a long time for and remembers forever.

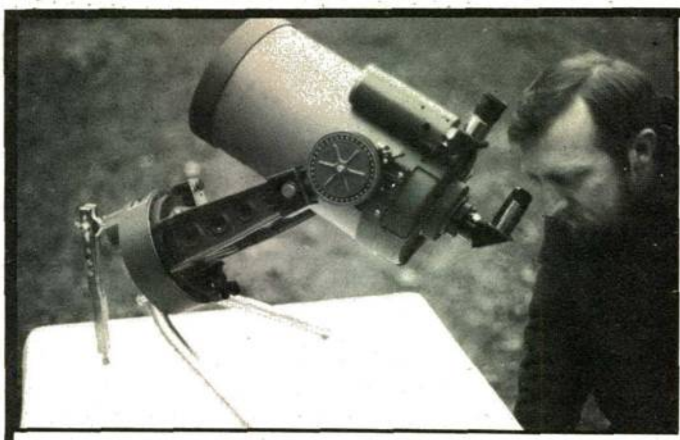
F.D. BRUNER
Hope, Ind.

Mr. Bruner / Thank you for sharing your observation. Since you stress quite strongly the perfect atmospheric conditions that prevailed the night you saw Encke's division, you obliquely reinforce the statement made in our article. We generally base our measurements of minimum required aperture on nights with so-called "normal" conditions. Encke's division is visible with an eight inch aperture on nights of superb seeing, but most of the time you'll need 10 inches.

Sir / In looking at the photograph of Mars on the cover of your January 1977 issue, I noticed what appeared to be Valles Marineris (the large canyon of Mars) in the upper left part of the picture near the terminator. I compared this with the photograph on page 11 which featured this canyon, and realized that they were the same. One thing puzzled me, however; it seems that one of these pictures must be inverted (not rotated) since both have the same side up but they are facing different directions. Am I correct?

ZEV GROSS
Flushing, N.Y.

Mr. Gross / Both the pictures you refer to in your letter have the same orientation. Your confusion may result from the difficulty in seeing the large, roughly oval, low contrast feature (shown on page 11) on the cover photo. This feature is located 2-5/8 inches (65mm) from the top and 2-3/4 inches (70mm) from the left on the January cover. On both photos, the canyon enters this feature from the "upper left" direction.



BUY YOUR NEW CELESTRON® 5 OR 8 TELESCOPE

from TUTHILL

Your BANKAMERICARD

master charge

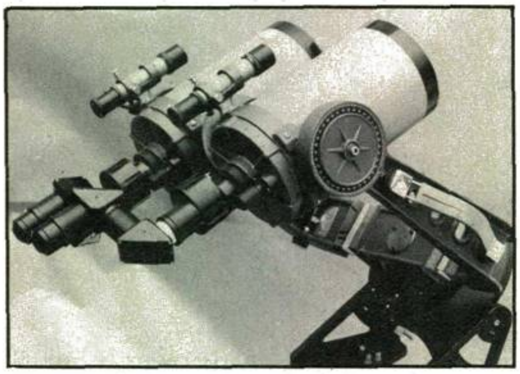
Stock Delivery

Demonstrations and Personal Consultation

MONEY SAVING OFFER — Save 10% on any of the valuable custom-engineered accessories listed below when ordered at the same time as you order your CELESTRON 5 or 8 telescope from us. All custom accessories can be mounted without special tools.

PRESENT CELESTRON OWNERS: Would you like to have increased protection from dewing — make lining up on the celestial pole a snap without leveling your tripod or knowing your latitude — look at the zenith easily with a large variable-power finder — adjust the tripod height for sitting or standing — increase the fine adjustment of the right-ascension knob — see the setting circles with built-in lights — have a five-pound sturdy portable equatorial mount which duplicates the wedge and tripod function but which stores in the box — motorize your manual declination adjustment — have a Precision Celestial Pole Finder — have a VELVET TOUCH™ helical eyepiece focuser — have a Precision Polar Axis Locator — carry your valuable scope securely with a sturdy retractable handle or put a UNITRON UNIHEX™ on your Celestron? Coming soon: Low cost DRIVEN R. A. and Declination circles with shaft encoders — no potentiometers.

INTRODUCING THE GEMINI V SYSTEM



CUSTOM ENGINEERED DUAL CELESTRONS — SUPER GIANT BINOCULAR TELESCOPE

If Percival Lowell had used our NEW GEMINI V System he might not have misunderstood what he saw on Mars. Everyone knows that you can see more with two eyes than with one. This is because the human eye-brain system receives twice as much information and the result is a keener view of detail and a confirmation of the reality of the image because of the comfort and the normalcy of the viewing.

This significant development in equatorially driven giant binoculars results from the rugged peas-in-a-pod precision optical performance of the Famous Celestron Telescopes as well as the elegant, easy-to-use fingertip collimation adjustments, the key to successfully viewing from 50 ft. to infinity with such a large system.

See people, birds, ships, planets, comets, or the Moon with or without eyeglasses. Get the sensation of three dimensions with views you have never seen before. Conversion of scopes to binocular mode does not alter original operation. Write for details of the GEMINI SYSTEM and our newly announced COMET AWARDS program.

ASK ABOUT OUR OFFER OF A FREE SOLAR-SKREEN* FOR YOUR SCOPE.

Money-Back Guarantee On All Products We Sell

WE HONOR MASTER CHARGE AND BANKAMERICARD.

ROGER W. TUTHILL, INC.

*Trade Mark

Box 1086A, 11 Tanglewood Lane, Mountainside, N.J. 07092

Telephone 201-232-1786

STRAIGHT TALK ABOUT EYEPIECES

You usually get what you pay for and eyepieces seem to be no exception. Eyepieces are the final key to good telescope optical performance. We offer the following eyepiece choices:

Kellners	**$18.50 ea.**
Orthoscopics	**$21.50 ea.**
Erfles	**$26.50 ea.**
Brandons	**$47.50 ea.**
and	
Clave Plossls	**$59.50 ea.**

These eyepieces span the viewing requirements of the casual observer to the most demanding professional. Write for a copy of an independent users report #Z-1000 for a detailed discussion of the essential points of comparison on these critical elements contributing to your astronomical enjoyment and satisfaction.

TRAP A STAR
with
NEW
STAR—TRAP™
illuminated reticle eyepiece

IDEAL FOR ALL FINDERS OR GUIDE SCOPES

- Self-contained switch and replaceable 6-volt battery
- Dual red light-emitting diodes (10-year life)
- *Matching molybdenum cross hairs*
- Adjustable brightness and focus
- Rubber eyecup
- *Only 8 ounces*

Model No. 1 — 27 mm. Kellner eyepiece	**$44.50**
Model No. 2 — 20.5 mm. Kellner eyepiece	**$47.50**

TUTHILL DRIVE SYSTEM

Equatorially mount your SLR camera or scope to this easy-to-use, lightweight, 117v, 60 Hz, *motor-driven* unit. Ideal for comet or constellation photography. Built-in safety clutches on both axes, large shafts, worm drive and a tubular Polaris locator supplied complete. Mounts directly to your camera tripod 1/4"-20 fitting.

Still only $99.50

AN ARRAY OF GREAT PRODUCTS
To Make Your Hobby More Enjoyable

THE STEREOOCULAR* ON A CELESTRON® 8

Lets you look naturally and restfully with two eyes. Gives great views of moon and planets. Some even claim to see a 3-dimensional effect.

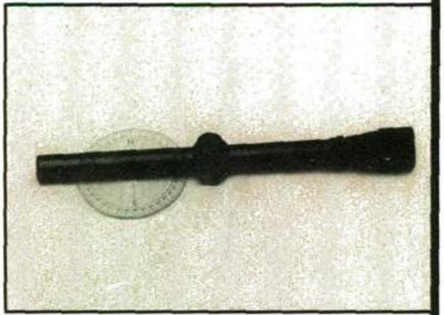
Fits 1-1/4" drawtubes on refractors or Cassegrain-type scopes. Used with matched eyepieces. Two persons can use at the same time.

Still only $244.00

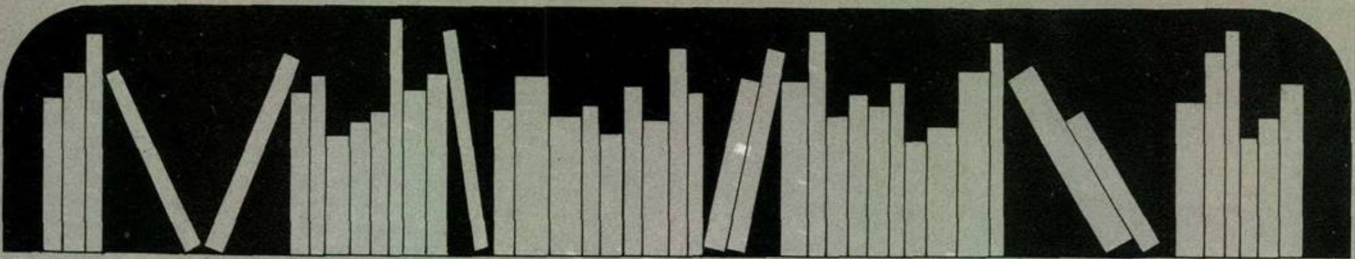
PRECISION POLAR AXIS FINDER*

Get perfect celestial pole alignment quickly and easily every time. When the centered 4x cross hairs are set directly on Polaris, the 0.9-degree offset barrel points precisely on the pole. Novel Polaris date and time chart supplied FREE.

From $31.50



NOTICE: We are now able to supply all your telescopic needs with CELESTRON Schmidt-Cassegrains, EDMUND SCIENTIFIC reflectors; our own RFT units and custom accessories for DYNAMAX scopes of all sizes. Ask about our FREE SOLAR-SKREEN* offer concerning these products. In addition, we can supply your needs for BRANDON eyepieces, STAR-TRAP* eyepieces, LUNA-SHADE* filters, 12v D.C. inverters, ELECTRONIC EYEBALL* guiders, SUPER STAR-TRAP* DRIVE CORRECTORS, CELESTRON binoculars, and many other items. Send now for our FREE catalog.



ASTRONOMY REVIEWS

Comet Kohoutek
edited by GILMER ALLEN GARY

272 pages, paperback $3.35*
NASA (1975)

The next time astronomers warn Earthlings of some impending celestial cataclysm, many people will simply refuse to believe them. The scientists did not improve their status as prophets by their forecasts of Kohoutek, the "comet of the century". Burned by their overoptimistic estimates, they may just keep quiet next time and let the whole world discover the next spectacular comet one night. Statistics imply that one is indeed on the way, though nobody can predict for sure. And nobody will dare guess!

But Kohoutek was not a disappointment for astronomers; it was the most studied and scrutinized comet in history. Coordinated under NASA's "Operation Kohoutek", dozens of observatories on Earth, on aircraft, balloons, rockets, satellites and deep interplanetary probes all watched this visitor from the edge of the solar system. A year later, scientists met in Huntsville to report on their preliminary findings.

This NASA book is a collection of papers presented there, along with transcripts of extensive discussion periods. Each team reported their observations in detail at a level aimed at other astronomers and space scientists; this is a major drawback of the book as it is not easy reading for non-astronomers.

Occasionally a summary article includes several pages of background and interpretation. Huebner's report on "The Structure of the Nucleus of Comet Kohoutek", Delsemme's "Molecular Processes in the Cometary Coma and Tail", Opik's "On Predicting the Brightness of Comets", and particularly Whipple's "Implications for Models and Origin of the Nucleus" are all excellent (if challenging) general interest pieces.

But other papers go into intricate detail on observing wavelengths, space chemistry, or spectroscopy. (Example from a discussion period: Q - Point of clarification. Did you use just $p_d d=4 \times 10^{-3}$? A - No, but that was the best fit.) This is not the kind of talk on which astronomy enthusiasts can easily eavesdrop.

Many of the sessions were devoted to space observations from Skylab and other satellites. (The papers on Mariner 10 and Copernicus observations were delivered, but were not included in this volume.) The comet's tail was probed by radio signal occultation techniques from Pioneer 6. An unsuccessful attempt was made to bounce a radar beam off the nucleus; this project revealed a maximum possible size for that structure.

The conference was primarily a NASA affair, with many American universities represented as well. Several European observers attended, since "Operation Kohoutek" had been a worldwide effort. Notably absent were Soviet astronomers, whose attempted ultraviolet observations from the manned Soyuz 13 spaceship evidently failed, and hence were never reported.

Perhaps the technical nature of most of the papers can even be used to an advantage. A college astronomy course (or even a high school science club) could parcel out the short papers to individuals or groups who would then research the techniques used and report on them to other students. The scope of astronomical observing is one of the striking images in this book, and it can be used as a good teaching point.

Looking at the results of the observations, one is tempted to agree with Opik's serendipitous remark: "We could say that the misjudged prediction for comet Kohoutek has turned out as a bonus, resulting in an unparalleled harvest of observations which no other comet could match." That harvest is amply exhibited in this book. *James E. Oberg.*

**Stock number 033-000-00598; available from U.S. Government Printing Office, Washington, D.C. 20402.*

Contemporary Astronomy
by EDWARD J. DEVINNEY JR.,
HAYWOOD SMITH JR. and
SABATINO SOFIA

342 pages, hardcover, $14.95
Charles E. Merrill Publishing Co. (1975)

Contemporary Astronomy is better than most introductory astronomy books. It does, however, have some serious deficiencies: no glossary (essential for an introductory level book), no discussion of life in the universe, and equations in the text.

The development of the book is pretty conventional, falling into three major parts: The first contains basic physics, historical and observational background, and instrumentation; the second deals with planets and stars, and the third with our galaxy, other galaxies and cosmology. The chapters and subtopics within each of these parts receive standard treatments. For a collaborative effort, the writing style is unusually uniform, informal and appropriate in level to the audience.

The opening chapter, "The Sky", is somewhat disappointing. It starts out by looking at the naked eye sky, but then quickly gets bogged down in coordinate systems, time and motions of Earth — material that would not spark the interest of students. The historical material in chapter two receives better than average treatment but with a few problems. For example, a diagram of the Ptolemaic system does not have the proper size ratio for the orbital paths of Mercury and Venus; in fact, these two planets are placed in the wrong order from Earth. Mars, Jupiter and Saturn do not have the radii of their paths parallel to the Earth-sun line. The authors state that the Copernican system was simpler than the Ptolemaic one; in fact, it was probably at least as complicated. They do correctly point out (and few books make this crucial point) that Copernicus could establish a scale model of the solar system from observation; such was not the case in Ptolemy's system.

The lack of emphasis on planets, black holes and possibilities of life in the universe is somewhat puzzling.

Despite these shortcomings, **Contemporary Astronomy** is a better than average introductory text with strong emphasis on stars and methods of observations. The illustrations are good, and the layout pleasing. The writing occasionally lapses into passive "scientific" prose, but generally holds up with a touch of humor here and there. *Michael Zeilik.*

Volcanos of the Earth, Moon and Mars

edited by G. FIELDER and L. WILSON

126 pages, hardcover, $19.95
St. Martin's Press (1975)

Classical poets have called the human eye "a window into the soul". Modern poets of comparative planetology might have a similar rhapsodic term for volcanos: "a window into the core" of a planet. Volcanos tell geologists and astronomers about a planet's interior heating and structure, the evolution of its atmosphere, and its dynamic processes. This well-written book tells us about planetary volcanos — a topic about as far removed from classical astronomy as is possible to imagine.

The study of lava from the bowels of Earth has intrigued one type of scientist, while the observation of celestial objects has fascinated another. But clear boundaries between the classical sciences have been fading in the past few years. Studying other planets and studying Earth as a planet is very much a part of contemporary astronomy and space science.

There are lava flows on the moon more than 600 miles across; similar structures are found on Earth and Mercury, while they're only suspected on Mars and Venus. But there are major differences between such formations which are born under different gravitational and atmospheric conditions. Future planetary explorers — specifically those sent in search of undiscovered volcanos — will need the detailed information given here to interpret their findings.

The book answers many questions which amateur astronomers may wonder about, but the answers are not simple ones. What caused the moon's sinuous rilles? What might cause the lights of the "lunar transient phenomena", and how are they related to the epicenters of moonquakes detected by Apollo instruments? Why do Earth, the moon, Mercury and Mars each have asymmetric distributions of volcanic activity over their surface?

To understand these explanations, a basic background in astronomy — as well as a little geology — is definitely required. Though written by a team of specialists, the book is quite understandable to the nonspecialist. It may be most appropriate for a college level course for geology and astronomy majors, but it can be tackled by a determined home reader. The illustrations are appropriate and the glossary indispensable.

Individual chapters discuss lava flows, explosive eruptions, volcanic gases (the probable source of the present atmospheres of all terrestrial planets), faults, rifts and calderas — terms becoming familiar to astronomers from photographs of other planets sent back by space probes. A chapter on shield volcanos contains two striking drawings comparing the Martian Olympus Mons to the Hawaiian Islands in cross section, and to England in area. (An even bigger volcano may have been detected on Venus by radar.)

The detailed pages of this surprisingly entertaining book reveal exactly how the study of photographs of volcanos on other planets can uncover secrets of age, internal morphology, past history and other facts. When this much can be learned at a distance, what lessons will await astrogeologists who set foot on other worlds? *James E. Oberg.*

◆

Outlook for Space

by DONALD P. HEARTH

NASA (1976)*

This is the long-awaited NASA study on future directions in space exploration. The result consists of two impressive volumes of options, charting different choices available to the United States in the future exploration of outer space. But somehow the study produced only a "roadmap and no compass".

Top NASA specialists from all of the space centers consulted, discussed and coordinated the text and tables. Outside analysts such as Norman Cousins, Margaret Mead and Jack Campbell tried to inject some vision and philosophy, but wound up simply providing a few handsome phrases for the frontispiece.

Still, the report is a valuable resource for space buffs and writers. After brief perspectives on the past space program and present trends, a list of future options is presented.

Many of the directions involve astronomical questions. Extraterrestrial themes, backed up by hard benefit studies, include questions about the fate of the sun, the formation and evolution of the solar system, and the formation, evolution and modification of planetary atmospheres including Earth's. Those and others are excellent scientific and practical objectives; inasmuch as this report lists and identifies them, it is useful.

The report does not ignore the promise of space industrialization, and the major realization that space solar power may really soon be feasible did not germinate until after the report was in its final stages. But again, the material presented here is helpful (though uninspired).

The second volume discusses different levels of technology — the gadgets — that will be the tools of the trade over the next 20 years. The engineers and rocket buffs will like this one better. *James E. Oberg.*

**Volume 1, stock number SP-386, paperback, $3.60. Volume 2, stock number SP-387, paperback, $4.00. Both available from Superintendent of Documents, Washington, D.C. 20402.*

◆

Space Science Involvement

by TALBOT MOUNTAIN SCIENCE CENTER

62 pages, $3.00*
American Radio Relay League (1974)

Astronomy often seems to be a bit lacking as an experimental science. The popular image involves scientists passively observing distant and unreachable phenomena, speculating about their meaning, and weaving theories about their observations.

Of course, there is more to it than that. Spectral analysis of starlight is connected with chemical laboratory work. Nuclear physics and associated sciences require extensive experiments. Manned and unmanned space probes might be considered a new phase of experimental astronomy. Even just observing (from a backyard, a mountaintop or a space station) can hardly be considered a passive activity.

So where does this leave young astronomers without physics labs or space stations who want to do some real experimental work? This unique booklet describes activities in radio telemetry, data reduction, orbit calculation, and other topics crucial to modern astronomy.

The subject is "Project OSCAR", which is the name of a series of tiny homemade satellites which have piggybacked into orbit on NASA and Air Force rockets. They are designed for use by amateur radio enthusiasts, and can be used for experiments by single individuals or by clubs and science classes. The book gives the lesson plans.

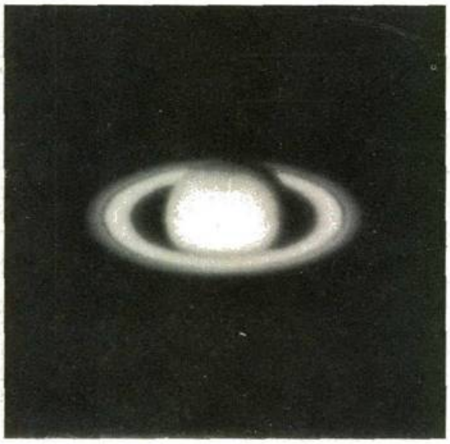
There are many opportunities for amateur astronomers with access to the appropriate radio gear. Telemetry patterns, orbits and atmospheric conditions are just a few of the subjects of interest.

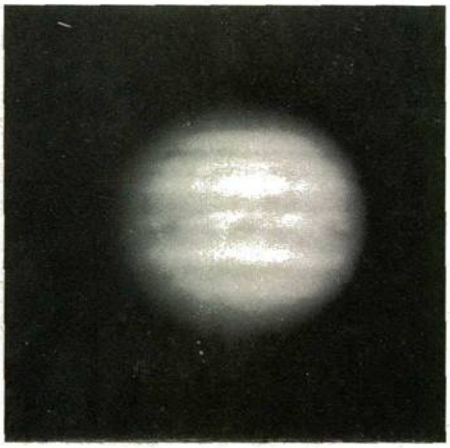
The second printing of this booklet has corrected some initial errors that appeared in the first edition. The activities described can be extremely educational and a lot of fun for amateur space scientists. *James E. Oberg.*

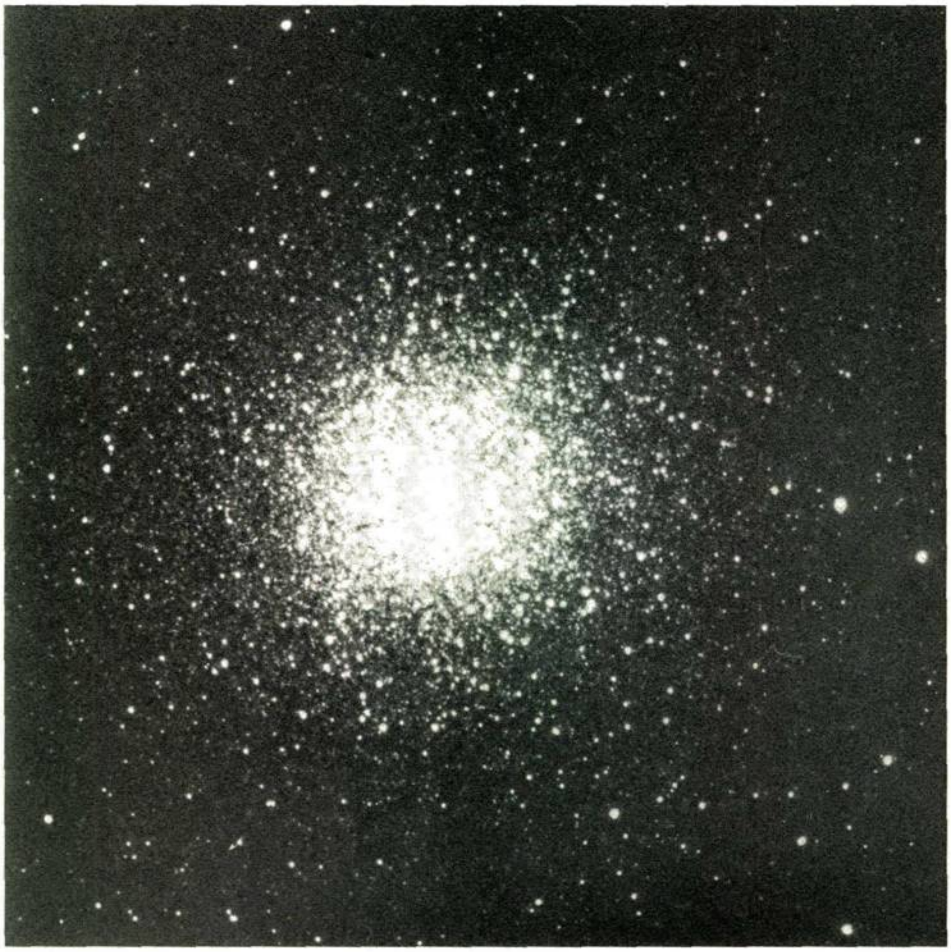
**Order from ARRL, 225 Main St., Newington, CT 06111.*

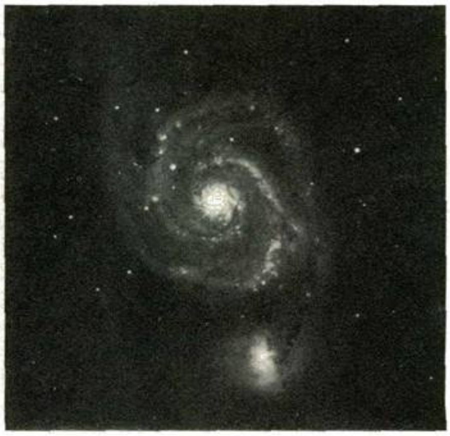
◆

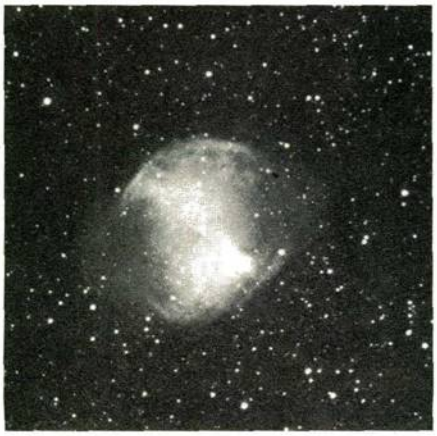
Details. Details. Details. They're a sign of excellence in astrophotography. And we can show you how to get them onto film. One way is with our Celestron 14, as shown by the photos below. But there are other ways. For details, write us. Celestron International, 2835 Columbia St., Box 3578-AM, Torrance, Calif. 90503.

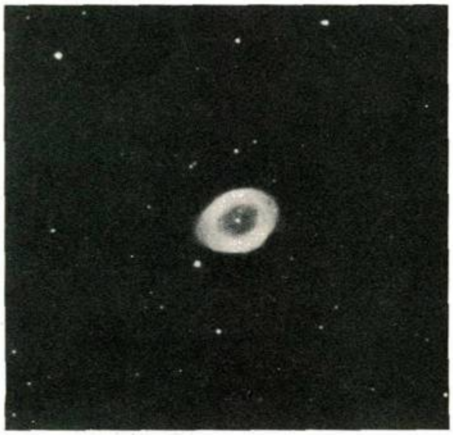

Saturn, 7 secs., SO-410


Jupiter, 5 secs., SO-410


Great Globular Cluster in Hercules, 20 mins., chilled Tri-X


Whirlpool Galaxy, 20 mins., chilled Tri-X


Dumbbell Nebula, 15 mins., chilled Tri-X


Ring Nebula, 20 mins., 103a-F

ASTRO-NEWS

Latest News From the World of Astronomy

More From Viking

Viking scientists described recent discoveries at a meeting of planetary scientists in January. Both landers and both orbiters are now functioning again after a shut-down period while Mars passed on the farside of the sun from Earth. First surface pictures returned after the shut-down revealed a more dimly lit landscape which Viking officials described as "murky". The familiar landscapes of Chryse and Utopia can still be seen toward the horizon, but apparently the atmosphere is not as clear as it was months ago. The increased opacity may be due to dust particles or local hazes. Instruments reveal that a fog of frozen water is now forming daily during predawn hours, but it dissipates by late morning.

Autumn began at the two landing sites on Jan. 4, and orbiter photos show that the north polar hood of carbon dioxide mist is forming at high latitudes. From this cloudy hood, frozen carbon dioxide will form on the ground creating the extensive north polar winter cap, just as winter clouds and snow are familiar at high latitudes on Earth. Winter clouds may also appear at Viking sites, although no features identified as distinct clouds have yet been seen by Viking. (Features called clouds on early photos are now ascribed to electronic camera effects during picture reproduction.)

Viking 2 samples of crumbly clods of crustlike soil had more sulfur compounds than most other soil samples, supporting the idea that they are a soil crust loosely bonded by sulfate evaporites left behind as moisture seeped up through the Martian dust and evaporated at the surface (see Astro-News, December 1976). Evidence seems to be pouring in that liquid water was present on Mars in the past, frozen water exists now at both poles and possibly in subsurface ice, and chemically bound water exists in soil minerals.

Orbiter photography of the poles shows gaps around the edges of the polar ice, revealing thick deposits of stratified sediments of a type first seen in Mariner 9 polar photos. Viking analyst James Cutts has found places where a lower sequence of strata is overlain by an upper sequence at discontinuous angles to the lower strata — a situation called a *geological unconformity*. Many investigators believe the strata indicate episodes of polar erosion and deposition, while the unconformities might change climatic conditions between one sequence of erosional episodes and another.

Just such a series of climate episodes seems to fit beautifully with a new theoretical result about Martian dynamics by non-Viking researchers Joseph Burns, William Ward, and Owen Toon of Cornell University and NASA. They have shown that Mars, in its present configuration, has a variable obliquity (tilt) of the polar axis toward the sun. Today, the tilt of Mars is about 25 degrees (Earth's tilt is about 23-1/2 degrees), but it varies roughly from 11 degrees to 37 degrees and back every 130,000 years, with maximum excursions every 1.3 million years. As long as the polar ice cap is not tilted more than about 35 degrees toward the sun, the cap stays too cold for the ice to melt efficiently — though at times of maximum tilt, the cap might get warm enough for much ice to disappear. Thus the cycle of changing tilt might create cycles of varying erosion and deposition at the poles, creating the stratified polar sediments.

But the most exciting result of the new dynamical analysis involves the effect of the huge Tharsis bulge of dense volcanic lava flows and volcanos. This bulge affects the Martian tilt. Before the bulge formed, Burns, Ward and Toon found that the tilt of Mars could range from about 22 to 44 degrees. With either pole tilted about 44 degrees toward the sun (summer for that pole and winter for the other), that pole's temperature would stay above freezing constantly during the summer months. The sun would not set during this time. What we now call the "permanent" water ice cap might have melted entirely, with the water carried in the air away from the warm pole toward the equator, and perhaps

Viking *continued on page 65*

Infrared Flux Collector Construction on Schedule

Construction of the world's largest infrared flux collector, the British 152 inch (3.8 meter) instrument in Hawaii, is proceeding on schedule for the target start-up date of January 1978. Astronomers were informed of this at a recent meeting of the Royal Astronomical Society in London by Jim Ring, chief project scientist and chairperson of the project's Steering Committee.

The term *flux collector* is used for the instrument rather than "telescope" because it has been deliberately designed to a coarser specification than would be needed for optical wavelengths, taking advantage of the fact that less mechanical accuracy is needed for acceptable observations at the longer infrared wavelengths. Because of this, the instrument is much cheaper than an equivalent optical telescope; Ring estimates its price as about $1.5 million. The site chosen, Mauna Kea, Hawaii, is one of the best infrared observing sites in the world. The altitude (13,796 feet) will keep the instrument above most of the air's water vapor which absorbs strongly in the infrared.

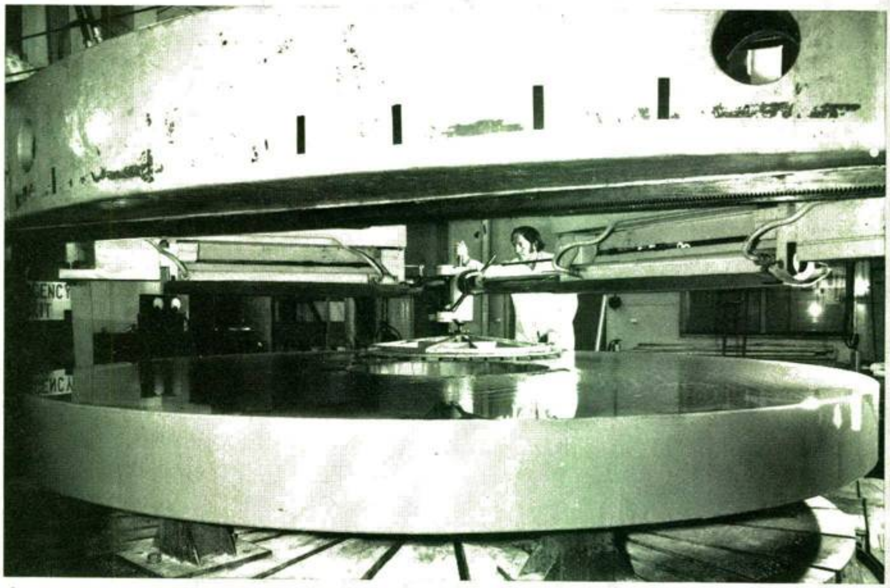
Observers will actually live at a halfway house 9,000 feet up the mountain, sharing dormitory facilities with French and Canadian astronomers who also have instruments on the mountaintop. Only during a working shift will observers travel up to the instrument itself — well above the worst of the weather, which has temporarily closed down building operations for the rainy season (as trucks cannot get up to the mountaintop).

In spite of this seasonal break in construction, the building for the instrument is now finished and awaiting installation of the dome, which has been built in the United States and will be shipped in the spring. The interior structures for the dome are nearing completion in Sheffield, England, and polishing of the mirror is at an advanced stage at the United Kingdom installation of Grubb-Parsons. Latest reports suggest that the mirror can be figured to better accuracy than planned, with the specified imaging of two to three seconds of arc improved to better than one second of arc in the final mirror.

This unexpected bonus will have the effect of halving the time needed for observations by improving the signal/noise ratio. Ring said the United Kingdom Science Research Council will effectively get double the instrument it has paid for.

The instrument will be guided by sophisticated computer systems, and will carry a variety of electronic sensors. Because all this equipment is designed around the original coarse specification, the pointing accuracy and other features of the flux collector will not be up to the usual standards of optical astronomy. But Ring agreed that although this is not an optical telescope, the improvements taking it beyond specification are sufficient that it may be useful for optical observations that do not require long exposure times.

Astronomical puzzles high on the list to be tackled by this powerful new infrared facility include cool clouds (in the process of collapsing to form stars) and the center of our galaxy (which in the infrared is much less obscured for optical observations by concentrations of dust in the plane of the Milky Way).



A technician is shown here grinding the rear surface of the primary mirror of the British Infrared Flux Collector. Photograph courtesy of the Royal Observatory, Edinburgh.

England's new infrared observatory (being built on Mauna Kea, Hawaii) is pictured in the early stages of construction. Photograph by Larry Kadooka.

Mauna Kea Observatories

The summit of Mauna Kea on the island of Hawaii is recognized as one of the finest spots on the globe for research astronomy, and the expansion of an already established international community of major observatories is now underway there.

The countries of Canada, France, England and the United States are currently involved in the installation of new optical and infrared telescopes on the 13,796 foot mountain. The summit area may support as many as 14 major telescopes, both optical/infrared and radio, by the turn of the century.

The value of the mountain for astronomy was first realized in 1963 when Dr. Gerard Kuiper of the University of Arizona conducted a worldwide survey of prospective locations for future NASA telescopes, and concluded that Mauna Kea was probably the best site in the northern hemisphere for astronomical observation.

Kuiper's conclusion led former Hawaii Gov. John Burns to set aside all land within a 2.5 mile radius of the summit as a "Science Reserve" district.

After the University of Hawaii (UH) Institute for Astronomy established an 88 inch (2.2 meter) optical telescope on the mountain in 1970, several foreign countries expressed an interest in the summit area for their own studies.

Canada, France and Hawaii are now building a 144 inch (3.6 meter) optical/infrared telescope. England has begun construction on its own 150 inch (3.8 meter) infrared flux collector, and the site has already been prepared for a 120 inch (3 meter) NASA infrared instrument.

The Canada/France/Hawaii telescope will be used primarily to pursue research in the ultraviolet and visible regions of the spectrum. England's observatory will be used solely for infrared studies of objects lying outside the solar system.

The NASA telescope would have supported the entire Mariner Jupiter/Saturn mission, but a crack which developed in the primary mirror during grinding delayed construction. The telescope should be ready to begin mission support in early 1979, prior to the first encounter between the spacecraft and Jupiter.

The three new observatories will join the existing 88 inch UH optical/infrared telescope, and two smaller 24 inch optical instruments — one operated by NASA for planet observation, and another used to support research at the large UH observatory.

The 88 inch telescope is used for a broad range of nighttime studies, but particular emphasis is placed on visible and infrared observations of the atmospheres of the major planets. The telescope is also used to study surface properties of minor constituents of the solar system. Studies of stellar atmospheres and their chemical and physical structure are also made, and the extremely dark sky above the mountain allows for observation of faint objects at the very edge of the observable universe.

Land at Hale Pohaku near the 9,000 foot level on the southern slope of Mauna Kea has been set aside for midlevel support facilities for scientists and technical staff members working at the summit. The area is considered ideal because of its proximity to the observatories (less than eight road miles), and because of the need for acclimatization for the scientists and other workers. Existing UH policy requires that astronomers remain at Hale Pohaku for at least 24 hours before using telescopes at the summit.

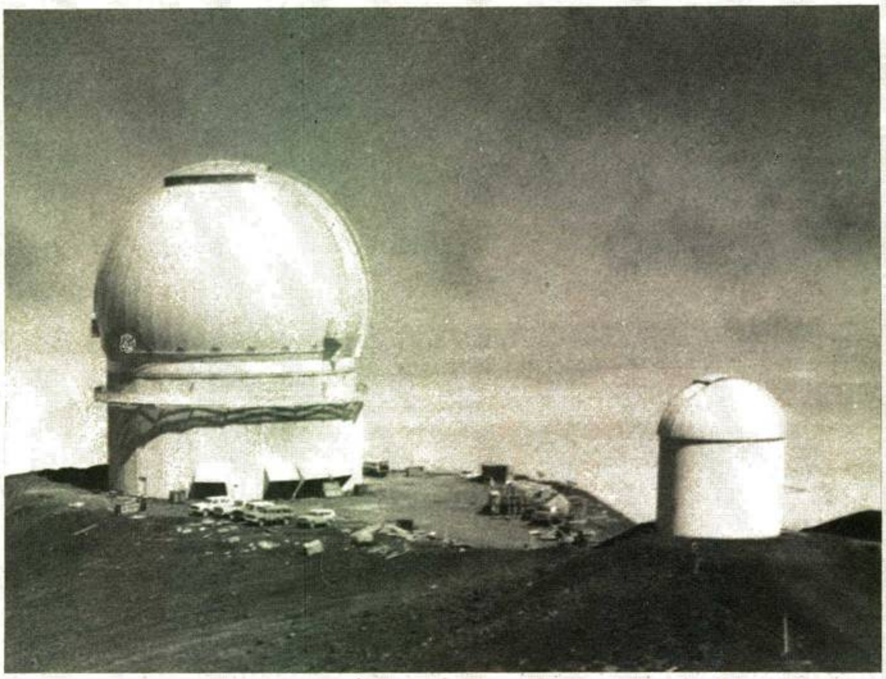
Dr. John Jefferies, director of the UH Institute for Astronomy, said recently that it is impossible to predict with any certainty the funding available around the world for major telescopes over the next 20 years. But based on his estimates, UH may expect to receive as many as 10 requests in that period for permission to construct in the summit area either large radio telescopes or optical telescopes of 100 inches or larger aperture.

Jefferies pointed out that many sites in the continental U.S. used for astronomical research have been compromised to some degree by air pollution and uncontrolled city lights. However, Mauna Kea is comparatively high and isolated, and protrudes through the clouds into a clean, dry atmosphere.

"These conditions combine to make the mountain known internationally, and promises for it a future as a major world center for ground based astronomy," he said.

Jefferies said a plateau just north of the summit cone where the existing optical telescopes are located could easily support as many as three single-dish radio and up to 10 optical telescopes, and another plateau east of the summit could support two interferometer instruments. In addition, another four major optical telescopes could be placed in the same area as the existing observatories near the summit, bringing to 23 the ultimate number of telescopes the mountain could support.

The University of Hawaii will receive 15 percent of the viewing time on the new 144 inch telescope, with Canada



The Canada-France-Hawaii Observatory seen on the left will eventually house a 144 inch (3.6 meter) optical/infrared telescope for research in the ultra-violet and visible regions of the spectrum. The 24 inch (.6 meter) optical NASA planetary patrol telescope is at right. Photograph by Larry Kadooka.

Mauna Kea *continued on page 64*

Model For Double Source Radio Galaxies

A new model proposed by R. Lovelace of Cornell University may explain double source radio galaxies. A massive black hole in the nucleus of a radio galaxy is responsible for the emission of ultrarelativistic protons, which in turn generate the radio sources.

Any model attempting to explain these sources must cope with an increasing body of observational data including the stability of the energy source over billions of years, the symmetry and alignment of the radio clouds, and the placement of the radio clouds perpendicular to the parent galaxy. (For a radio photograph of such a source, see "Radio Interferometry", ASTRONOMY, October 1976.)

Lovelace proposed that a black hole with a mass on the order of 100 million solar masses in the nucleus of a galaxy attracts a thin accretion disk that contains substantial mass and is hot enough to be electrically conductive. Mass in the disk would be supplied by the addition of gas — and sometimes entire stars — from the region of the galactic nucleus. The disk, aligned parallel to the plane of the parent galaxy, gains material from stars and gas initially orbiting inside the galaxy. Material from the galaxy brings with it a weak magnetic field that is strengthened and compressed in the accretion disk.

Inside the accretion disk (approximately the size of the solar system), an intense electrical and magnetic field will accelerate electrons and protons to enormous energies, bringing them very close to the speed of light. The particles are directed by the fields out of the accretion disk at right angles to its plane. The energy in such a powerful natural dynamo comes from the gravitational potential energy of the infalling matter. The power emitted in the particle beams alone is fantastic: 100 billion times greater than the entire energy output of the sun.

Well outside the galaxy, the electron and proton beams interact with each other, intergalactic gas, and their own magnetic fields to emit radio waves by the synchrotron process (in which electrons spiral about magnetic field lines, losing energy). Depending on the strengths of the magnetic fields, the model can explain a wide range of observed radio emitting regions, from a few to millions of light-years in diameter.

Sun Spinning Faster According to Scientist

Since 1967 the sun has been gradually spinning faster on its axis. According to Dr. Robert Howard of the Hale Observatories, the increase amounts to five percent near the equator, or from 4,500 to about 4,750 m.p.h. (7,200 to 7,600km per hour). The acceleration is greatest 10 to 15 degrees on each side of the equator rather than at the equator itself, and then tapers off toward the poles.

The changes in rotational velocity must be only skin deep, Howard said. They probably affect only the photosphere (the white-hot solar atmosphere). If they went deeper, they would require an enormous amount of energy.

Howard's observations were made with the 150 foot tower telescope at Mount Wilson Observatory.

The velocity gain could be caused by the sun's magnetic fields, he said. It is known that these magnetic fields, which rise to the surface of the 864,000-mile-diameter gaseous sphere, move faster than the flowing gas they "plow" through. Thus they could serve as "paddles" to accelerate the surface gas.

The fields indicate that something inside the sun is rotating faster than the surface — perhaps some internal dynamo mechanism. The sun makes one complete rotation in little over 27 days.

The velocity gain probably is part of the 11 year solar cycle, Howard said. However, this cannot be determined for a while because the tower telescope has been measuring the velocities of the magnetic fields and gas on the sun for only nine years. If the solar cycle is involved, Howard would expect the velocities to slow down again.

The current cycle is an unusually long one and will last more than 11 years. The cycle is near or in its quiet phase. The fact that the length of the cycles vary indicates they are affected by large scale phenomena.

The tower telescope now makes 24,000 observations covering the solar surface each day. Two solar phenomena are observed: magnetic fields and motions of the solar gas. The results are sent to observatories and universities throughout the world.

Magnetic observations are made with a spectrograph that views only a green metallic line of iron. The sun's magnetic field splits this spectral line in two parts in what is called the Zeeman effect, which discloses the presence, strength and polarity of magnetic fields. Movement of the fields is determined by observing the day-to-day change in their positions.

The motion of the solar gas is measured by obtaining the Doppler effect of light near the edges (limbs) of the sun. This gives the direction and velocity of the gas.

Mauna Kea *continued from page 63*

and France splitting the other 85 percent.

Jefferies said the university has assumed responsibility for the design and construction of the NASA telescope. Following completion of the facility, university astronomers will be entitled to 30 percent of the viewing time for their own programs. He also said the NASA telescope "will represent a very significant addition to the capabilities of the university for its advance toward an authoritative program of research and graduate training in this (infrared) area."

The other infrared telescope under construction is being funded entirely by the British government, and UH scientists are expected to receive a still undetermined amount of viewing time.

The expansion of the astronomical community atop Mauna Kea has generated much discussion on the island because of alleged conflicts between the interests of astronomers, hunters, wildlife and primitive-area conservationists, and snow skiers.

Environmentalists are concerned that certain unique natural features of the mountain might be disturbed by increased activity at the summit and at Hale Pohaku. One of these features is Lake Waiau at around 13,000 feet. The lake is unique because of its elevation and its permafrost bottom which keeps it from percolating away into the porous lava rocks. Another unique feature is a native forest area which encircles the mountain between 6,000 and 10,000 feet elevation; this area is the home of the endangered Palila bird.

According to Jefferies, construction at the summit in the future will be limited to one observatory at a time. Since astronomy is essentially a non-polluting activity, Lake Waiau and other features of the mountain will not be disturbed.

Award Established for Comet Discovery

Roger W. Tuthill has established a special award for the discovery of comets. A citation and an award of $250 will be made to the American nonprofessional astronomer who discovers a new comet during 1977.

No limit has been placed on the size or type of instrument to be used in making the discovery, but it must be made visually — not photographically. The award must be claimed within 90 days of International Astronomical Union recognition (the naming of the comet after the discoverer).

If no comet is discovered by midnight, Dec. 31, 1977, Tuthill has stated that the program may be extended. Tuthill, president of Roger W. Tuthill, Inc., is interested in fostering the search for comets, as well as giving recognition to the need to create more widespread interest in astronomy. Inquiries may be sent to Comets, Box 1086, Mountainside, N.J. 07092.

British Discover Two New Novae

Two novae discovered by British observers were visible three degrees apart in evening skies early in 1977. Following George Alcock's discovery of a nova in Vulpecula (see Astro-News, February 1977), John Hosty found a nova in Sagitta, close to the star Alpha Sagittae.

Hosty (who used 1/2 of a broken pair of 10x50 binoculars for his discovery) noted the star at magnitude 7.2 on Jan. 7. His finding was confirmed by fellow observers on following nights.

Unlike Alcock's nova — now designated NQ Vulpeculae — which varied erratically for two weeks before fading, Hosty's nova proved to be of the more straightforward, medium fast type, and quickly dimmed in brightness. Backtracking and examining the Palomar Sky Survey prints revealed no stars brighter than 20th magnitude in the prenova position. This means that the nova had a brightness range similar to that of NQ Vulpeculae — an increase of about 100,000 times. It is probably at a similar distance of roughly 6,000 light-years, which means the nova actually erupted around 4000 B.C.

By the end of January, Hosty's nova had faded to below ninth magnitude. Alcock's nova underwent a slight brightening around the same time, from 12th to 11th magnitude.

Viking *continued from page 61*

all the way to the other cap. Obviously, this would create a radically different climate during the periods of 44 degree tilt than the climate we see now. More generally, the pre-Tharsis series of climate cycles would have been different from the present post-Tharsis series.

Since the Tharsis volcanos may have formed during a relatively brief period of Martian time, the shift from the one group of climate cycles to the other may have been rapid, accounting for the unconformity in polar sediments.

These dynamical results, still more generally, may be a solution to the mystery of the Martian channels and other evidence of ancient liquid water, since the water evaporated from the polar ice might rain or snow out of the air in other Martian regions, eventually running off in erosion channels.

Orbiter photographs of the Olympus Mons volcano gave another recent hint about Martian erosion. As known since Mariner 9, the base of Olympus Mons is marked by a towering cliff. Pre-Viking investigators suspected that this might be a recent erosion surface or fault cut into the older lavas. But telescopic Viking views show that Olympus Mons lava flows cascade from the upper slopes of the volcano over the cliff and out onto the adjacent plain. Thus the lavas are more recent than the cliff — whatever its origin — and have not been eroded. This agrees with other evidence that the last flows of the Olympus Mons volcano may be quite young, in geological terms.

Venus Light Confirmed

Recent results of Soviet and American space exploration have confirmed a phenomenon on Venus reported by generations of professional and amateur visual observers. Known as the ashen light, this phenomenon is a dull glow or coloration on the dark side of Venus, reported on rare occasions.

During the 1976 flights of the Russian probes Veneras 9 and 10, Soviet scientists detected a glow from the dark side, consisting of a series of spectral emission bands. The glow is strongest 56 miles (90 kilometers) above the Venusian surface.

At the January 1977 meeting of planetary scientists in Honolulu, University of Colorado scientists C.A. Barth and G.M. Lawrence reported identification of the emission bands. The bands are caused by glow created from the combination of oxygen atoms in Venus' high atmosphere. The oxygen atoms probably arise from breakup of oxygen molecules (O2) due to action of sunlight on Venus' sunlit side. Circulation of the atmosphere, taking about four days, brings the atoms around to the dark side where they recombine and emit the glow, which is spread through the visual part of the spectrum in at least 10 distinct wavelengths or colors. The strongest is at wavelength 4792 Angstroms.

The glow is strongest on the dark side near the evening terminator with a decrease toward the dawn terminator, but the glow is also patchy and variable. Variations in numbers of oxygen molecules brought to upper atmosphere levels by vertical currents may cause fluctuations in the total brightness from day to day. This agrees with old visual observations of ashen light, which indicate that the phenomenon may be visible on a few days but absent on most other days.

The maximum intensities observed by the Russians are strong enough to be seen by visual observers on Earth, confirming that the phenomenon could have been recorded by visual observers. The whole phenomenon is believed to be similar to the airglow of Earth, a faint light in our night sky that can be detected by instruments, which varies somewhat from place to place and time to time.

BRIEFS

- A team of scientists at NASA's Ames Research Center is working on a new kind of photosynthesis for converting sunlight into chemical energy and food. This study has important implications for understanding basic life processes.
- NASA's Lewis Research Center is applying space technology to develop a nickel-zinc battery which may eventually help reduce our nation's petroleum consumption.

ASTRO-MART

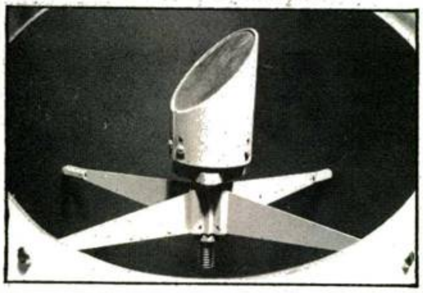
FREE CLASSIFIED ADS
to ASTRONOMY subscribers only.

As a noncommercial subscriber you receive two free 40 word classified ads each year as a privilege with your subscription. Commercial advertisers must pay for their ads; rate cards are available on request.

ASTRO-MART

Astro-Mart is a free, reader service department available only to current, paid, noncommercial subscribers; 2 ads are allowed per year. Each ad submitted must not exceed 40 words in length (including name, address, etc.). All ads are subject to editorial review for suitability. Be sure to allow 3-4 months for your ad to appear.

SECONDARY HOLDERS AND SPIDERS



Newtonian diagonal holders in stock for most sizes. Lightweight aluminum construction with continuous retaining rim — no tabs to increase diffraction. Carefully designed to prevent strain on optics. Spiders feature high tensile strength stainless steel vanes.

ALUMINIZED ELLIPTICAL DIAGONALS

Fine annealed Pyrex. Listed by minor axis size.

1.30"..$8.00 1.52"..$11.50 1.83"..$13.50
2.14"..$16.50 2.60"..$19.50 3.10"...$29.95

Write For Free 24 Page 1977 Catalog

Includes valuable information on how to determine accurately the proper size diagonal for your needs.

13 Newtonian mirror mounts, 4-1/4" to 16"
22 Diagonal holders, 1-1/4" to 4-1/2" minor axis
24 Spiders, for tubing from 5" to 24"
8 Rack and pinion focusing mounts

Also extensive selection of Cassegrain mirror mounts, Cassegrain secondary holders, tube counterweights, ring mounts, star diagonals, guide telescopes, illuminated and regular cross-hair eyepieces, information booklets and many other telescope items.

KENNETH NOVAK & CO.
Box 69A
Ladysmith, WI 54848
Phone: 715-532-5102

***Astronomy Island** *Bermuda*

THREE VACATIONS IN ONE

on a 7-day cruise for the starry-eyed. The elegant s.s. Statendam, the fantastic islands of Bermuda and breathtaking skies combine to make this fourth annual venture another week of joy. Nationally prominent experts will take you on tours of the heavens at sea and on land. The ship departs from N.Y. City, July 16th and returns on the 23rd. Per person fares begin at $529.06.

Write for details.

ASTRONOMY ISLAND LTD.
P.O. Box E —— Dept. A.
Brooklyn, N.Y. 11202
212/834-1888

FOR SALE — Complete Dynamax 8, right angle viewer, porro prism, 5 eyepieces, diagonal, Pentax adapter. Never used. Price: $925.00; you pick up. Contact Dick Myers, Browning Rd., Hyde Park, NY 12538. Phone (914) 266-5953.

FOR SALE — Two 29" x 24" McCall prints: Armstrong, Aldrin and Apollo; Orion leaving space station for Earth as in 2001. Price: $50.00 inc. Write James Ryan, 6 Beacontree Rd., Leytonstone, London, ENGLAND E11 3AX.

FOR SALE — U.S. space stamps in mint sheets and blocks. Includes Pioneer, Mariner, Apollo/Soyuz and others. Also first day covers of historic manned, unmanned spaceflights. Send SASE for free price list to Robert A. Yajko, 123 Summit St., R.D. #4, Leechburg, PA 15656.

ASTROFILMS IN 36-exp 35mm ROLLS

Now obtain the most popular films for Astrophotography

- Spectroscopic with antihalation rem-jet backing
  Order 103aF, 103aE, or 103aO **$6.25** ea.
  3 or more (any combination) **$5.50** ea.
- SO-410 (planets, moon, sun) **$2.20 ea.**
- High Contrast Copy (planets, full moon, sun) **$2.20 ea.**
- 2475 Recording ASA 3200 at short exposures **$2.70 ea.**

Film information included with order, 35¢ separately

ASTROFILM
P.O. Box 2731, Dept. AM
Akron, OH 44301

CELESTRON TELESCOPES
ON DISPLAY AND IN STOCK

E & W OPTICAL, INC.
2420 EAST HENNEPIN AVE.
DEPT. AM
MINNEAPOLIS, MINN. 55413
612-331-1187
SEND FOR PRICE LIST "A"—
Astronomy supplies and accessories.

"Priceless . . ."

'Your Astronomy courses are excellent. Never have I undertaken any educational course where the school was more interested in actually wanting its students to LEARN what was taught, rather than issue a passing grade. What I have learned is priceless. Many thanks."

Jack D. Ellis, Oklahoma City, Oklahoma

Coast Navigation School specializes in individual instruction. Call or write today for our free course catalog describing our streamlined home study courses designed especially for amateur astronomers.

CELESTRON Schmidt-Cassegrain and UNITRON refractor telescopes available.
Special prices on course/telescope combinations.

Coast Navigation School of Astronomy
Dept. 5340 418 E. Canon Perdido
Santa Barbara, CA 93102 / 805 963-7837

I'm interested! Please send me your free school catalog.

Name
Address
City
State, Zip

NEWTONIAN NOTES

Designing and Building a High Performance Telescope from Commercial Components.

Topics include guides to selecting telescope type, f-ratio, and limits of performance. Extensive information on Rich Field telescopes. Guides are given to help select eyepieces, focusers, diagonal size, spiders, finders, etc. Drawings and text include construction of a high performance, 5" aperture Schmidt camera from commercial parts including optics for under $150. Special considerations for photographic use are covered. Telescope tube assembly instructions include how to lay out holes, making the large focuser hole, finding length of tube, and detail collimation instructions. Can be used to upgrade your present telescope.

NEWTONIAN NOTES by Peter Francis, 52 pages, 8-1/2 x 11, $4.45 ppd. Add 4% sales tax in Wis.

Kenneth Novak & Co.
Box 69B Ladysmith, WI 54848
Tel. 715-532-5102

FOR SALE — Off-axis guiding system as sold by Celestron. Includes 12mm illuminated reticle ocular. Price: $50.00. Write Austin L. Parker, 5207 Williams Dr., Fort Myers Beach, FL 33931.

FOR SALE — Celestron 8, wedge, tripod, Barlow, 2 eyepieces; excellent optical and physical condition. Price: $800.00. Contact Don Brassea, 51 Roadrunner, Arizona City, AZ 85223. Phone (602) 466-5088.

FOR SALE — 8" f/7 Cave reflector with Edmund equatorial mount, clock drive, circles, homemade pedestal, saddle, 3 eyepieces. Price: $450.00 Also ASTRONOMY Magazines (August 1973 to present). Contact Chuck Hall, 870 N. Fern St., Orange, CA 92667. Phone (714) 532-5552.

FOR SALE — Criterion RV-6, 2 eyepieces, custom right angle viewfinder, setting circles, electric drive, slow motion control. 1 year old; new condition. Price: $350.00. Contact R. S. Herbage, 679 Demaris Ct., Burlington, Ontario, CANADA L7L 5C9. Phone (416) 632-8663.

FOR SALE — Midland Portable - Mobile 23 channel, 5 watt CB radio with battery and telescopic antenna. Mounting brackets, jacks for external extensions attached. Like new. Price: $200.00 or best offer. Write Karl Pittelkau, Rt. 1, Bethel Academy, Warrenton, VA 22186.

FOR SALE — Litronix AC adapter for calculator. Specifications: 50 MA, 4 volt DC, 8 watt output. Has female plug and 72" extension. Will sell for $5.00. Write Karl Pittelkau, Rt. 1, Bethel Academy, Warrenton, VA 22186.

Idaho Seminars In Astronomy

Session I — Aug. 7-13, 1977
Session II — Aug. 14-20, 1977

Combine a study of astronomy with an outdoor vacation for you and your family. Camp and study the stars at Idaho's Farragut State Park on scenic Lake Pend Oreille, in the heart of the Northwest recreation area.

Seminars . . .

—are suitable for beginners and experienced amateurs

—have facilities which include a 16 inch Celestron and several smaller telescopes

—are available for college credit, if desired

—offer a unique family vacation

—are staffed by professional astronomers and experienced teachers

For brochure and further details contact:

University of Idaho
Idaho Summer Seminars
in Astronomy
Continuing Education
Moscow, Idaho 83843
Phone (208) 885-6745

---

4 OPTICA b/c CATALOGUES

(1) "Telescopes and Accessories" — complete instruments, observational accessories, over 250 items. (2) "Astrophotography" — largest selection of astrophoto systems, supplies, special films, processing materials, over 500 items. (3) "Publications & AVA" — over 300 books, atlases, maps, slides, posters, recordings, globes. (4) "ATM" — complete selection of goods for the amateur telescope maker, integrated fiberglass sytems, over 400 parts plus materials and services. Each catalogue — 50¢; all four — $1.50, for handling and postage. Send cash, check, or U.S. stamps. Also receive FREE Astronomical Events Calendar — a wealth of useful information.

OPTICA b/c Company,
Sales/Service Division
4100 MacArthur Blvd., Oakland, Calif. 94619

8" f/5
TELESCOPE
$219.50

EQUATORIAL
MOUNTING

TWO
EYEPIECES

TELESCOPE IS COMPLETE, THERE IS NOTHING ELSE TO BUY. Specifications are: 9-1/4" by 40" tube, 40mm, and 25mm Kellner eyepieces, rigid equatorial mounting. Packing charges $4.00. $219.50 f.o.b.

10" F/5 TELESCOPE $299.50

Equatorial mounting, 25mm eyepiece, 12" by 52" tube, 6 power finderscope. $299.50 f.o.b. $16.00 packing charge

SUPERIOR OPTICS
2984 FAIR AVE., DEPT AM
COLUMBUS, OHIO 43209

MARS PHOTOS

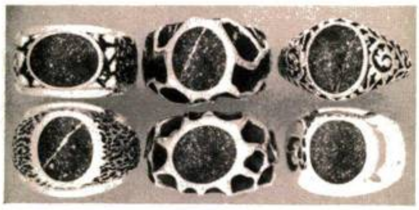
Enjoy the breathtaking landscape of Mars as taken by the U.S. Viking mission. Very high quality 23" by 35" **full color blow-ups** on fine Chrome-Coat paper with Liquid Laminate. Ideal for use in schools and clubs, as well as your own living room.

Only $4.95 each postpaid
Calif. residents add 6% sales tax.

WOODSTOCK PRODUCTS
P.O. Box 4087, Dept. AM
Beverly Hills, California 90213
Phone: 213-650-6602

METEORITE RINGS

Now in 14Kt. Gold or Sterling Silver



The only rings on Earth with stones from outer space. Only $28.50 in sterling silver or $85.50 in 14kt. gold. For free brochure write: **HOUSE OF RINGS**
P.O. Box 6127, Dept. AM,
Kansas City, MO 64110
Phone: 816-363-2002

SLIDES PRINTS POSTERS

from the
KITT PEAK
NATIONAL OBSERVATORY
and the
CERRO TOLOLO INTER-AMERICAN OBSERVATORY

M42 (NGC 1976)·The Orion Nebula, Kitt Peak 4 meter photo

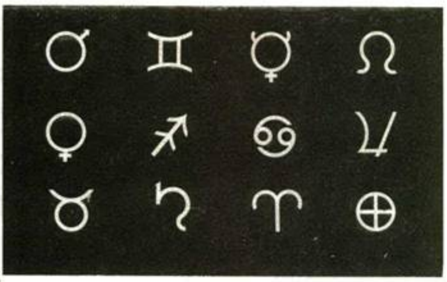
These "sister" observatories, Kitt Peak in Arizona and Cerro Tololo in Chile, operate twin 4-meter (158-inch) telescopes, and provide facilities and instrumentation capable of exploring the entire celestial sphere.

Now, for the first time, you can purchase color and black and white 35 mm (2" x 2") slides of celestial objects photographed with the telescopes of these two National Observatories. More than 100 subjects, including Northern and Southern Hemisphere objects, telescopes and instrumentation, and observatory scenes, are available.

Selected subjects are also available in large color transparency form, color and black and white prints, and color posters.

For a complete listing and prices, send $1.00 (check or money order, please) for an illustrated 44-page catalog to:

Catalog—Public Information Office
Kitt Peak National Observatory
P.O. Box 26625
Tucson, Arizona 85726



ASTRONOMY

Indexes

ASTRONOMY's cumulative subject Index to Volume 3, 1975 covers the months of January through December 1975 (issue Nos. 1 through 12). Index to Volume 3 is available for $1.25** each.

Index to Volume 1 and Index to Volume 2 are also still available for only $1.00** each.

***Be sure to enclose an additional 25¢ per order for postage and handling.*

Order your indexes today!

ASTRONOMY
411 E. Mason, Sixth Floor,
Milwaukee, WI 53202

CELESTRON
UNITRON
VERNONSCOPE
UNIVERSITY OPTICS
ASTRO-PHYSICS
DOAA
DEL N. WOODS

Telescopes, binoculars,
telephoto lenses,
spotting scopes, oculars,
drive correctors, cameras,
barlows, filters,
latitude adjusters,
books & atlases

It is our continuing goal to offer the finest astronomical instrumentation available combined with the consultation, demonstration, and service that is important to your satisfaction.

Most items delivered from stock.
Call, write, or drop in

DAVID A. POTTER
723 Cedar, Dept. A
Sandwich, IL 60548
(815) 786-8168

master charge
THE INTERBANK CARD

FOR SALE — DOAA AD-1 drive corrector; $55.00. 200mm f/2.8 Kowa lens/Nikon; $85.00. 35-85mm Vivitar/Nikon; $199.00. 40mm wide Kellner, 1-1/4"; $15.00. 16mm wide angle Brandon; $25.00. Celestron photo back, telextender, declination cable; $5.00 each. Write Thomas Adamo, 50 W. 93rd St., #8P, New York, NY 10025.

FOR SALE — RV-6 as advertised, plus 2 extra eyepieces, Barlow, camera mount, mounted 2.4" guidescope, accessories. Price: $350.00 (delivered), or $325.00 (you pick up). Contact Fred Ames Jr., 463 7th Ave., Troy, NY 12182. Phone (518) 235-2536.

FOR SALE — Back issues of ASTRONOMY: December 1974 through January 1977. Excellent condition. Make offer. Contact Charles E. Platt, R.D. #1, Box 257, Chester Springs, PA 19425. Phone (215) 827-7540.

Advertise it free in Astro-Mart.

FOR SALE — 20x60mm binoculars, 3.2 field view. Tripod adapter, leather case included. Very good condition. Price: $60.00. Contact Don Richardson, 508 12th St. N.W., Minot, ND 58701. Phone (701) 839-0857.

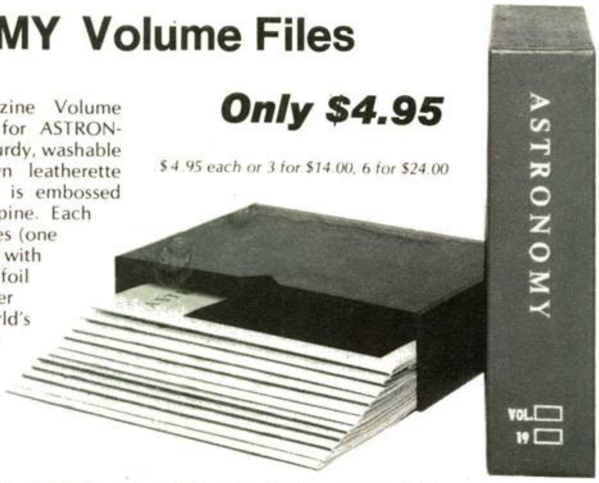
FOR SALE — Journals published by America's oldest optical society, 1943-1973 (missing 8 issues). Unusual opportunity for library or observatory. Valued at over $1,200.00. Price: $350.00 plus shipping. For details, contact Alfred C. Webber, Box 97, Chadds Ford, PA 19317. Phone (215) 793-1129.

ASTRONOMY Volume Files

Custom designed magazine Volume Files are now available for ASTRONOMY subscribers. These sturdy, washable cases have a rich brown leatherette finish, and ASTRONOMY is embossed in elegant gold on the spine. Each case holds 12 80-page issues (one complete year), and comes with a slip of gold signature foil to fill in volume number and year. Keep the World's Most Beautiful Astronomy Magazine beautiful year after year with this impressive addition to your library.

Only $4.95

$4.95 each or 3 for $14.00, 6 for $24.00



To order, simply fill in and mail the attached coupon today!

Use this address **ONLY** for Volume File orders and correspondence regarding them.

ASTRONOMY Volume Files
P.O. Box 5120
Philadelphia, PA 19141

Enclosed is $________ in payment for the following ASTRONOMY Volume Files:

______ 1 for $4.95 ______ 3 for $14.00 ______ 6 for $24.00

Name ____________________

Address ____________________

City __________ **State** ________ **Zip** ________

U.S.A. orders only. Allow 3 weeks for delivery.
Full money back guarantee.

NEW! CELESTRON 8 DEC. MOTOR DRIVE

It's easy to add a top quality electric declination drive to any Celestron 8 telescope. Our compact unit mounts in minutes, **no drilling or modification.** Looks great; low profile drive is tucked under fork arm. Allows normal manual dec. adjustment. Pushbutton forward/reverse hand control uses 9-volt battery (included). ***Instant refund if not fully satisfied.*** Immediate shipment. Drive and hand control complete only $59.95. (Specify scope serial number.) Send check or M.O. for free USA shipping. Master Charge, B of A accepted. Phone orders OK (sorry, no collect calls). *Drive correctors, many other items in free catalog. Write for yours today.*

GIESELER ELECTRONICS
730-C San Juan Av., Santa Cruz, CA 95065
(408) 423-1984

SPACE NOTE CARDS

Two New Sets of Full Color 4"x6" Note Cards with Envelopes!

Art work by Geoffrey Chandler and Morris Scott Dollens. Each artist has 8 exquisite paintings represented. Each set of 8 is $4.50 plus 50¢ postage (per set), Calif. res. add 6½%. Mail orders to:

PETERPRINTS
P.O. Box 1705—Dept. AS
San Francisco, Ca 94101

ALLOW 3-4 WEEKS FOR DELIVERY

OTHER SPACE ITEMS ON THE WAY — WRITE FOR NEWS

FOR SALE — Professionally built 6" combination Newtonian-Cassegrain telescope; 1 minute interchangeable secondaries. For use as f/4.5 RFT or f/22.5 long focus. Excellent condition. Contact Don Brassea, 51 Roadrunner, Arizona City, AZ 85223. Phone (602) 466-5088.

FOR SALE OR TRADE — Criterion Dynatrack variable power supply. Price: $60.00. Contact Don Scott, 1614 Tapir Circle, Ventura, CA 93003. Phone (805) 647-6184.

FOR SALE OR TRADE — 3" f/10 Optical Craftsman reflector. Excellent guidescope. Price: $45.00. Contact Don Scott, 1614 Tapir Circle, Ventura, CA 93003. Phone (805) 647-6184.

FOR SALE OR TRADE — 8" f/7 Criterion Newtonian with driven mount, circles. Price: $300.00. Contact Don Scott, 1614 Tapir Circle, Ventura, CA 93003. Phone (805) 647-6184.

TRADE — 16" f/3 parabolic mirror, aluminized and overcoated this year. For $120.00 (face value) in U.S. SILVER coins with legible dates (dated 1950 or before). For details, write Bob Kimmel, 1120 Woodruff Ave., Hillside, NJ 07205.

WANTED — Back issues of ASTRONOMY to complete small town library's collection: Vol. 1, Nos. 2 through 5; Vol. 2, Nos. 1 through 8; Vol. 3, Nos. 11, 12. Must be in excellent condition. Send condition, price only to Brett W. Huber, 107 Furnace St. Elyria, OH 44035.

WANTED — Back issues of ASTRONOMY: August 1973 through October 1975. Must be in good condition; will pay up to $70.00. Also indexes to Volumes 1 and 2; will pay $5.00. Write Walter Kummer, 17578 Cambridge, Lathrup Village, MI 48076.

WANTED — Copy of science fiction book, "Two Hundred Years to Christmas" (author unknown); will pay $10.00 Also need good B&W photo of NGC-6231. Give price. Write Bill Mahan, Box 1151, Alamosa, CO 81101.

WANTED — Speaking engagements for lecturer on astronomy, space colonization, the case against UFOs, similar topics. Write James E. Oberg, Rt. 2, Box 1813, Dickinson, TX 77539.

WANTED — Equatorial mount suitable for 4" Unitron refractor. Contact Jerome Salador, 55 Cherokee Ave., West Islip, NY 11795. Phone (516) 669-3998.

WANTED — Correspondence on Zeta Reticuli Incident, reputed star map in Betty Hill - UFO story. Astronomy enthusiasts with unique interpretations of "Hill map" should contact Bob Sheaffer, 9805 McMillan, Silver Spring, MD 20902.

WANTED — January 1976 issue of ASTRONOMY; will pay good price. Also complete set of ASTRONOMY: August 1973 through December 1975. Write M. Thomas, 8 Esplanade, St. Clair, Dunedin, Otago, NEW ZEALAND.

WANTED — Correspondence with man (preferably scientist) knowledgeable in fields of astronomy, cosmology, philosophy. Write Charlotte Wardell, P.O. Box 1091, Boulder, CO 80302.

WANTED — 8" reflector with accessories. Write E.M. Sanders, 303 Bay St., Gadsden, AL 35901.

Close-up on a distant neighbor.

Documenting one of the most exciting episodes in recent space exploration—the Mariner 10 spaceflight to the planet Mercury—this fascinating new book contains over 100 superior-quality, high-resolution photographs from the mission, revealing details of the planet's surface as well as geographical and geological data only guessed at before. With an authoritative text that puts the drama of the flight in the context of the current events of the day,

FLIGHT TO MERCURY

Bruce Murray and Eric Burgess

$12.95 at bookstores or from

COLUMBIA UNIVERSITY PRESS

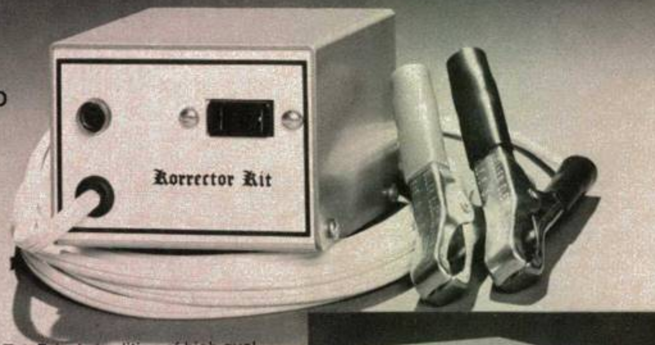
Address for orders: 136 South Broadway, Irvington, N.Y. 10533

$37

ASSEMBLED

$26

KIT



In keeping with TeleDrive's tradition of high quality at realistic prices, we now offer an inexpensive alternative to our deluxe control systems. Korrector Kit is well suited to a wide variety of applications, from simply driving your clock drive from 12 volts DC during visual observing sessions, to planetary photography, or even deep sky photography with your own manual declination control. The 8 watt output is ample for most telescopes, and the low price makes it ideal for a second system or a budget minded first one.

The entire unit is so compact (2 x 3 x 4 inches) that a separate control box is unnecessary. Pushbuttons for fast and slow speeds (about 80 Hz and 40 Hz respectively) are mounted on the rear panel along with the basic speed trim control. The front panel has the pilot light, battery cord, and AC outlet for your clock drive. If the box is held with the front panel facing down, the cords will trail straight down and all 3 controls will be on top and easy to reach with one hand.

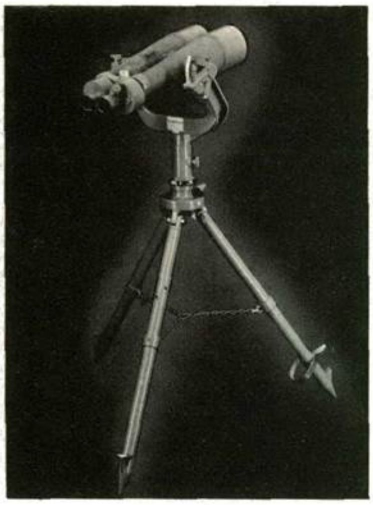
If you know how to solder, you can build Korrector Kit. The 6 page instruction manual is very easy to follow and assumes practically no experience with electronics. This is a complete kit, with all high quality parts. All that is needed for assembly is a soldering iron and solder, screwdriver, and small diagonal cutters. And, because of the simple, no frills construction, you should be able to build it in less than 2 hours. For those who prefer a ready to use drive corrector, the factory assembled unit is still the lowest cost high quality unit available.

Send your check or money order for immediate, postpaid delivery. Our money-back guarantee applies, of course.

TeleDrive
COMPANY

1571 Piedmont Rd.
San Jose, CA 95132
(408) 923-5344

Giant Binoculars



Discover the excitement of comet seeking!

This remarkable instrument really should be called a binocular telescope. The giant 120mm. objectives give breathtaking views of the night sky. Waterproof construction. Individual diopter adjustment. Fully coated optical system. Interpupillary adjustment. 3 degree field. Weight 120 lbs. Price includes holding arm, tripod, and cabinets.

20x120mm. **$2,995.00**

2" O.D. DIAGONAL

This high quality unit screws on the Celestron 8 allowing the use of 2" eyepieces. First surface mirror. 1¼" adapter included....... **$120.00 ppd.**

Standard 2" unit. Same high quality as above but fits standard 2" focusing mount. No adapter included. Price .... **$109.95 ppd.**

PROFESSIONAL DRIVE CORRECTOR

Probably the most advanced drive corrector in its price range. This heavy duty A.C.-D.C. unit features a unique new pulsating speed control light allowing you to check output against line frequency even in total darkness. Full 15 watt power output. Switch for solar, lunar, and sidereal drive rates. Remote control features fast-slow buttons and variable Hz dial. This compact unit slips right inside the Celestron wedge. 20 feet of battery cable and A.C. plug provided.
Price .... **$84.95 ppd.**

MIRROR CELLS

These new cast aluminum mirror cells are expandable to fit any size tube from 6¾" to 11". Fully adjustable with collimation locks. Design allows for proper tube ventilation.

For 6" mirror $12.50 ppd. For 8" mirror $14.50 ppd.

PRECISION SETTING CIRCLES

We have a nice line of precision setting circles at reasonable prices. A popular seller is a 6" solid aluminum model with machine engraved numbers. Shaft size ¼" to 1½" **$25.00/pr. ppd.** Send for our complete listing.

New Free Catalogue

Giant Eyepieces

An excellent selection of large eyepieces to meet your most critical viewing needs.

While we offer these new 2" O.D. eyepieces for the magnificent Celestron 14, they will give superior performance in any telescope. The wide-field, low power views offered by these eyepieces are truly remarkable. All are fully coated and have carefully corrected lens systems. Precision machined aluminum cells with chrome barrels.

40mm. Orthoscopic	**$59.95 ppd.**
32mm. Erfle (Wide-field)	**59.95 ppd.**
60mm. Kellner	**45.95 ppd.**
50mm. Kellner	**45.95 ppd.**
32mm. Erfle (1¼" O.D.) Same excellent quality as above, but has special spiral focusing cell and 1¼" adapter	**59.95 ppd.**
60mm. Kellner (model B) Low power at a low price. Our budget priced unit	**$29.50 ppd.**

NEW 8x50 VIEWFINDERS

Excellent quality wide-field finders with 50-mm objectives and smooth spiral focusing. Cross-hair reticle in Kellner eyepiece. Diagonal prism and dual mounting rings included. White enamel tube.

8x50mm. (Right angle)	**$38.95 ppd.**
8x50mm. (No right angle)	**$33.95 ppd.**
Celestron Model: Same as above only with special bracket for Celestron 8. Right angle prism. **Handsome orange color**	**$42.95 ppd.**

CELESTRONS

If you are thinking of buying a new Celestron, we invite you to call us for advice, prices, and delivery.

We are one of the Midwest's leading Celestron dealers. We offer the excellent C-5 or C-8 models at factory prices. We also make custom Celestron accessories. Please give us a call at 313-761-0430.

Canadian customers: Remember, we are only a 40 min. drive from Windsor, Ontario. Drive down and pick-up your new Celestron.

CAMERA ADAPTERS

Adapt your camera directly to any focusing mount. Use either first focus or eyepiece projection. For all 1¼" focusing mounts including Celestron. Threaded for our astro filters. Camera quality construction.

Pentax, Praktica, Mamiya	**$16.50 ppd.**
Nikon, Nikomat	**$24.50 ppd.**
Olympus OM-1	**$25.50 ppd.**
Canon, Minolta, Miranda	**$24.50 ppd.**

ASTRO FILTERS

Excellent quality at reasonable prices! All are dyed-in-the-mass plane parallel optical glass. The metal cells are threaded so that any number of filters may be "stacked" together. Filter colors: Ultra-violet, Orange, Red, Green, Yellow-Green, Blue, Medium Yellow. Neutral Density, 20%, 40%. **Price $5.00 each ppd.**

Variable Density Polarizing Filter. Two optical glass polarizing filters mounted in metal cell. Density varies with cell rotation. **$10.00 ppd.**

Gift with every order

University Optics, Inc.

2122 East Delhi Road
Ann Arbor, Michigan 48106

WANTED — Correspondence with persons enthusiastic about future of manned space exploration, conquest of the New Frontier. Also persons interested in Arthur Clarke's writings; adventure of interplanetary intergalactic exploration; "2001: A Space Odyssey", etc. Write Paul Domine, 909 School Dr., Waukesha, WI 53186.

WANTED — Regular correspondence with high school students interested in Star Trek. Write Jim Cole, R.R. #3, Box 292, Decatur, IL 62526.

WANTED — Back issues of ASTRONOMY: Vol. 1, Nos. 2,3,4,5 (will pay $4.00 each if mint condition); Vol. 2, Nos. 1,2,4,5,8, 12 ($3.00 each if mint condition). Issues in less than mint condition considered; state price, number, condition. Write Chesley Morton, 3083-K Colonial Way, Chamblee, GA 30341.

WANTED — 2x Barlow (1-1/4"); 1-1/4" wide-angle eyepieces (20mm-60mm); filters, sun screen for Criterion RV-6; wide-angle to telephoto lenses for Minolta XK. Write Marvin Abraham, R.D. #6, McKay Rd., Amsterdam, NY 12010.

Advertise it free in Astro-Mart.

WANTED — January 1976 issue of ASTRONOMY. Must be in excellent condition. Contact Aldo Erdic, I-83 Limbrick Square, Thunder Bay, Ontario, CANADA P7C 4S8. Phone (807) 577-6842.

INFORMATION WANTED — On theories on propulsion systems; environmental systems for interstellar or intergalactic ship. Also diagrams, models of design of the ship. Write Frank Adams Jr., 301 Hill St., Moscow, PA 18444.

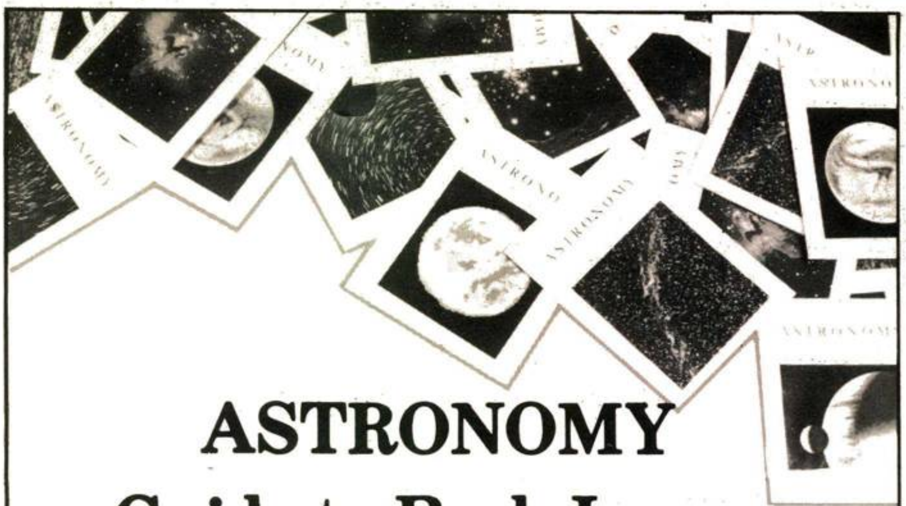
POSITION WANTED — In astronomy or related field. Am an amateur astronomer with extensive observational experience; have B.A. in physics, comprehensive knowledge of photography, some teaching experience. Contact Tom Bryant, 2000 Walnut - #32, Boulder, CO 80302. Phone (303) 442-6910.

ANNOUNCEMENT — The H.H. Astronomical Association is holding an astronomy fair for papers, photos. Open to any high school or college student. For competition details, write P.O. Box 492, Hibbing, MN 55746.

ANNOUNCEMENT — National Amateur Astronomers' Convention will be held Aug. 10-13, 1977 at University of Colorado in Boulder, with participation of AL, ALPO, IOTA, WAA. For information, write Denise Nye, NAA Convention Registration, 5604 Bowron Pl., Longmont, CO 80501.

ANNOUNCEMENT — Northeast Regional Convention of the Astronomical League will be held May 20 & 21 at Science Building, Keene (N.H.) State College. For details, write (before May 1) Walter A. Singer, Chairman NERAL, 7 Main St., Keene, NH 03431.

FREE — "Comet News Service" rapidly notifies you of bright comet discoveries, provides observing information, reviews the latest developments in cometary astronomy. Quarterly. Send long, self-addressed stamped envelopes to McDonnell Planetarium, 5100 Clayton Rd., St. Louis, MO 63110.



ASTRONOMY

Guide to Back Issues

Reader interest in back issues of ASTRONOMY magazine is higher than ever. As a result, our stock of back issues is swiftly dwindling. Below is a guide to ASTRONOMY back issues that are still available. For your convenience it is updated monthly; issues not listed are depleted. **The July 1976 History of American Astronomy issue is specially priced at $3.50 per copy plus postage.**

When ordering, please clearly state quantity, volume, number, month and year for each issue (first issue was August 1973), and include payment with your request. If issues ordered are no longer available, unless you instruct us to forward a refund or substitute issues, we will automatically extend your subscription appropriately.

***$1.50** per copy*

U.S. — Add $1.00 per order

Canada/Mexico — Add $2.00 per order

All Other Foreign — Add $2.50 per order

Vol. 1, No. 1 - August 1973	Available	Vol. 4, No. 2 - February 1976	Available
Vol. 2, No. 3 - March 1974	Short Supply	Vol. 4, No. 3 - March 1976	Available
Vol. 2, No. 6 - June 1974	Depleted	Vol. 4, No. 4 - April 1976	Available
Vol. 2, No. 7 - July 1974	Short Supply	Vol. 4, No. 5 - May 1976	Available
Vol. 2, No. 9 - September 1974	Short Supply	Vol. 4, No. 6 - June 1976	Available
Vol. 2, No. 10 - October 1974	Depleted	Vol. 4, No. 8 - August 1976	Available
Vol. 2, No. 11 - November 1974	Short Supply	Vol. 4, No. 9 - September 1976	Available
Vol. 3, No. 1 - January 1975	Depleted	Vol. 4, No. 10 - October 1976	Available
Vol. 3, No. 5 - May 1975	Available	Vol. 4, No. 11 - November 1976	Available
Vol. 3, No. 6 - June 1975	Available	Vol. 4, No. 12 - December 1976	Available
Vol. 3, No. 7 - July 1975	Available	Vol. 5, No. 1 - January 1977	Available
Vol. 3, No. 8 - August 1975	Available	Vol. 5, No. 2 - February 1977	Available
Vol. 3, No. 9 - September 1975	Available	Vol. 5, No. 3 - March 1977	Available
Vol. 3, No. 10 - October 1975	Available	Vol. 5, No. 4 - April 1977	Available
Vol. 3, No. 11 - November 1975	Available	Vol. 5, No. 5 - May 1977	*NYP
Vol. 3, No. 12 - December 1975	Available		

*Not Yet Published

Please allow at least four (4) weeks for delivery.

Rosemary L. Pickart
ASTRONOMY Magazine
411 E. Mason, 6th Floor
Milwaukee, WI 53202
(414) 276-2689

ASTRONOMY
ASTRONOMY
ASTRONOMY
ASTRONOMY

SITMAR'S SOLAR ECLIPSE CRUISE.

THE ECLIPSE IS ONLY PART OF THE ADVENTURE.

On October 12, 1977, Sitmar's Liberian-registered luxury ship, the T.S.S. Fairwind, sails to a point 1200 miles southwest of Los Angeles to provide an unequaled vantage point for viewing one of nature's rarest spectacles—a total eclipse of the sun.

But Sitmar will offer far more than a spectacular view.

Aboard will be Sitmar's "Science at Sea" program, featuring distinguished experts such as Dr. Edward M. Brooks, Boston College; Dr. Mark Chartrand III, Hayden Planetarium; Dr. Frank D. Drake, Cornell University; Dr. Carl Sagan, Cornell University; and Mr. Walter S. Sullivan, New York Times.

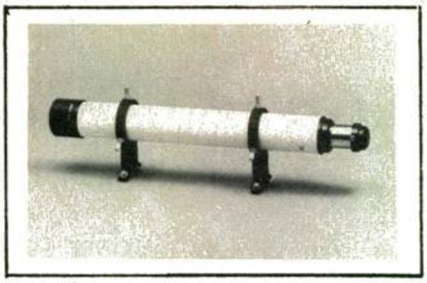
All this in addition to visits to popular ports, lavish continental cuisine, and a 500-man Italian crew.

Fly free roundtrip from any of 127 cities aboard regularly scheduled airlines for the 17-day cruise departing Port Everglades, Florida on October 1. With our "Cruise Plus" feature, you'll even enjoy stopover privileges.

For more information, see your travel agent.

Sitmar Cruises
The Caribbean and South America. Mexico. Canada and Alaska.

For an Eclipse brochure, write Sitmar Cruises, 1801 So. Hill Street, Los Angeles, CA 90015. Include name and address of your travel agent.



NEW 10X50mm VIEWFINDER!

Exceptional viewfinder of 10X power with 50mm aperture. Can also be used for a Guidescope in astrophotography. Coated optics, cross hair reticle. Double ring mounting brackets.
Complete **$48.00**

ALSO AVAILABLE:

Mirrors, Focusers, Spiders, Mirror Cells, Complete Telescopes from 4-1/ 4" to 12-1/ 2", Equatorial Mounts, Setting Circles.

EYEPIECES

Popular 1-1/4" O.D. Kellner and Orthoscopics.

Kellners: 6-mm., 12-mm. f.l. 40-mm. f.l.	$10.50
Orthoscopics: 4-mm., 5-mm., 6-mm., 9-mm., 12.5-mm., 25-mm. f.l.	$15.00

Or. 4mm
Or. 6mm
Or. 9mm
Or. 12.5mm
Or. 25mm

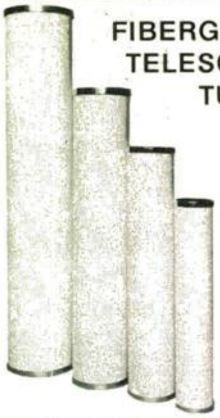
Prices effective for a limited time only!

VIEWFINDERS

Left: 8x 50mm. Gives you wide-angle viewing — Exceptionally good finderscope for large reflectors. Coated optics, cross-hair reticle. Double ring mounting brackets included. **$24.00**

Right: 6x 30mm. An excellent quality finder giving wide-field views of the sky. Coated achromatic objective with cross-hair eyepiece. With adjustable mounting bracket. **$14.50**

FIBERGLASS TELESCOPE TUBES



100% fiberglass tubes. Low thermal conductivity, highly rugged and durable, flat-black interior.

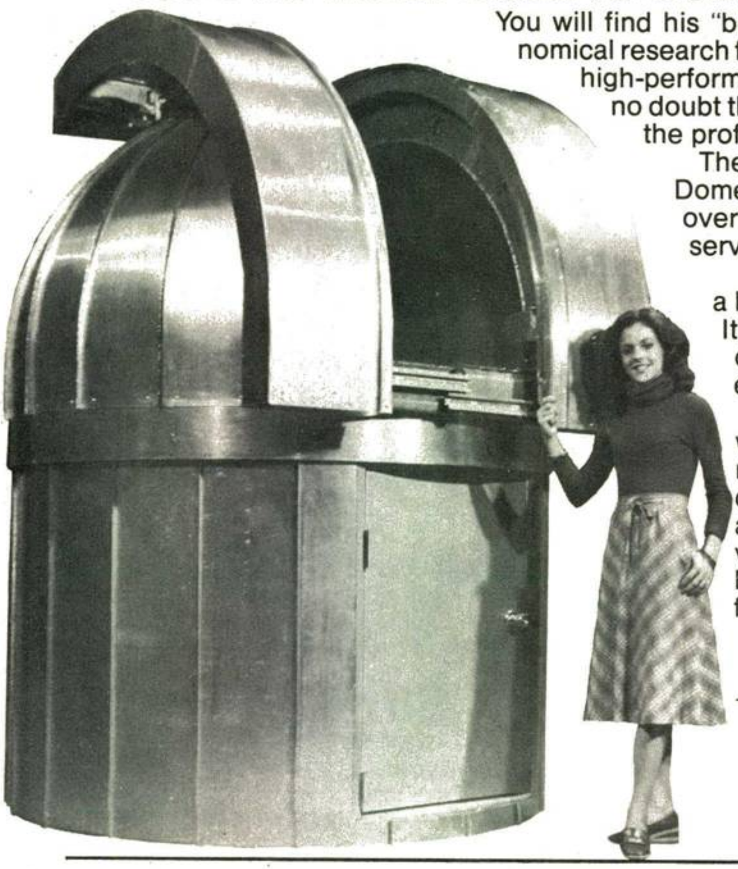
For a 6" mirror:	
7" I.D. x 31" to 52"	**$29.50**
7" I.D. x 53" to 60"	**$31.50**
Rings $6.50 a pair	
For an 8" mirror:	
9-1/2" I.D. x 38" to 55"	**$35.00**
9-1/2" I.D. x 56" to 60"	**$39.50**
9-1/2" I.D. x 61" to 66"	**$42.50**
Rings $7.50 a pair	
For a 10" mirror:	
12" I.D. x 40" to 48"	**$54.00**
12" I.D. x 49" to 62"	**$59.00**
12" I.D. x 63" to 72"	**$65.00**
Rings $9.50 a pair	
For a 12-1/2" & 14-1/4" mirror	
15-3/4" I.D. x 48" to 59"	**$70.00**
15-3/4" I.D. x 60" to 69"	**$82.00**
15-3/4" I.D. x 70" to 79"	**$87.50**
15-3/4" I.D. x 80" to 96"	**$115.00**
Rings $15.00 a pair	

Other lengths also available.

Tubes 7" and 9-1/2", $3.00 packing charge; 12", 15", 18", $5.00 packing fee; 20", $6.00 packing fee.

W. R. PARKS
P. O. Box 6683 Torrance, Calif. 90504
(213) 532-6066

The Two-Meter Observa-Dome Standard Aluminum Series



You will find his "big brothers" at almost every professional astronomical research facility in the free world. With the advent of today's high-performance catadioptric astro-telescopes, there can be no doubt that their requirements are just as rigid as those of the professional astronomer.

The outstanding quality of the two-meter Observa-Dome is precisely the same as professionals the world over have come to know and respect. Traditional Observa-Dome quality has not been sacrificed for price.

The two-meter aluminum Observa-Dome is not a kit; it comes fully heliarc-welded and assembled. It is ready to place atop your own base, or its own optional cylindrical base assembly complete with entrance door.

Perhaps the most amazing story is the price—which is due to modern mass production techniques and over twenty years' experience in the design and manufacture of observatory domes and systems to the highest professional observatory standards!

Exclusive sales agency in USA & Canada for the incomparable ZEISS Planetarium.

Tel. (601)982-3333

Observa-DOME
LABORATORIES, INC.
P.O. Box 885
Jackson, Mississippi 39205

STAR DOME

APRIL

by
James Mullaney and Henry J. Phillips

High in the northern sky on April nights rides that most distinctive of star patterns, the Big Dipper. Even more than Orion, the Big Dipper is known to the least experienced stargazer, and being in the sky all year round for most parts of the northern hemisphere, it's the starting point in just about every guidebook to the constellations. No other group of stars is so familiar to us all, and none other can spark quite the same feelings of friendliness and intimacy with the stars.

But, precisely because it's so famous, the Big Dipper tends to get short shrift from observers whose knowledge of the sky has developed past this group of stars alone. People who quickly learn the names of the first magnitude stars often remain totally unaware that each of the Big Dipper's stars also has a name. With such a famous group of stars, this is tantamount to not knowing the names of members of one's own family. So let's run through the Big Dipper stars individually and find out a little about them.

Alpha Ursae Majoris — the upper star at the end of the Dipper's bowl — is called Dubhe. This name is an abbreviation of the Arabian title for this star, which was Thahr al Dubb al Akbar (the back of the great bear). Dubhe is an orange star of spectral class K0, lying about 105 light-years away. At magnitude 1.81, it's the second brightest of the seven stars that comprise the Dipper.

South of Dubhe is Merak (Beta Ursae Majoris); its name comes from the Arabian Al Marakk (the bear's loin). Merak, at magnitude 2.37, is not as bright as Dubhe — even though it's somewhat closer at only 78 light-years distance. Merak is a white, main sequence star of spectral class A1.

Merak and Dubhe together are sometimes called the Pointers, because they indicate the location of Polaris, the north star. If you draw a line from Merak through Dubhe and extend this line about five times its own length, you'll hit Polaris. So with the Big Dipper in the sky all year round, you'll always be able to find north — a handy thing to know if ever you're lost in the woods (and can remember in which direction your campsite lies).

The bottom of the Dipper's bowl is marked by Merak and Phecda (Gamma Ursae Majoris) a few degrees east. Also known as Phad, this star's name is again from the Arabian (Al Fahdh, the thigh). Phecda's magnitude is 2.44, which makes it almost as bright as Merak; it's also a white, main sequence star (spectral class A0), located 90 light-years away.

North of Phecda, and marking the spot where the Dipper's handle joins the bowl, is Megrez (Delta Ursae Majoris). This word is from the Arabian Al Maghrez, the root of the tail. Megrez is markedly dimmer than any of the other stars in the Big Dipper; at magnitude 3.30, it's almost a full magnitude fainter than Phecda, second dimmest star of the seven — this despite Megrez' being the nearest of all the Big Dipper stars, only 63 light-years away. It is a white, main sequence star of spectral class A3.

Next to the faintest of the seven is the brightest. Alioth (Epsilon Ursae Majoris), the first of the three stars in the handle, shines at magnitude 1.79, slightly brighter than Dubhe. The derivation of the word Alioth is uncertain; it may be from the Arabian Al Hawar, the white of the eye (meaning the star was intensely bright). Alioth is a white star of spectral class A0, 68 light-years away.

The middle star in the Dipper's handle is Mizar (Zeta Ursae Majoris) — probably the only one of the seven whose name is fairly well-known. The name Mizar is from the Arabic Mi'zar, which means girdle or waistcloth — quite inappropriate for the great bear! Mizar, 88 light-years away, is a white main sequence star of spectral class A2, and shines at magnitude 2.26.

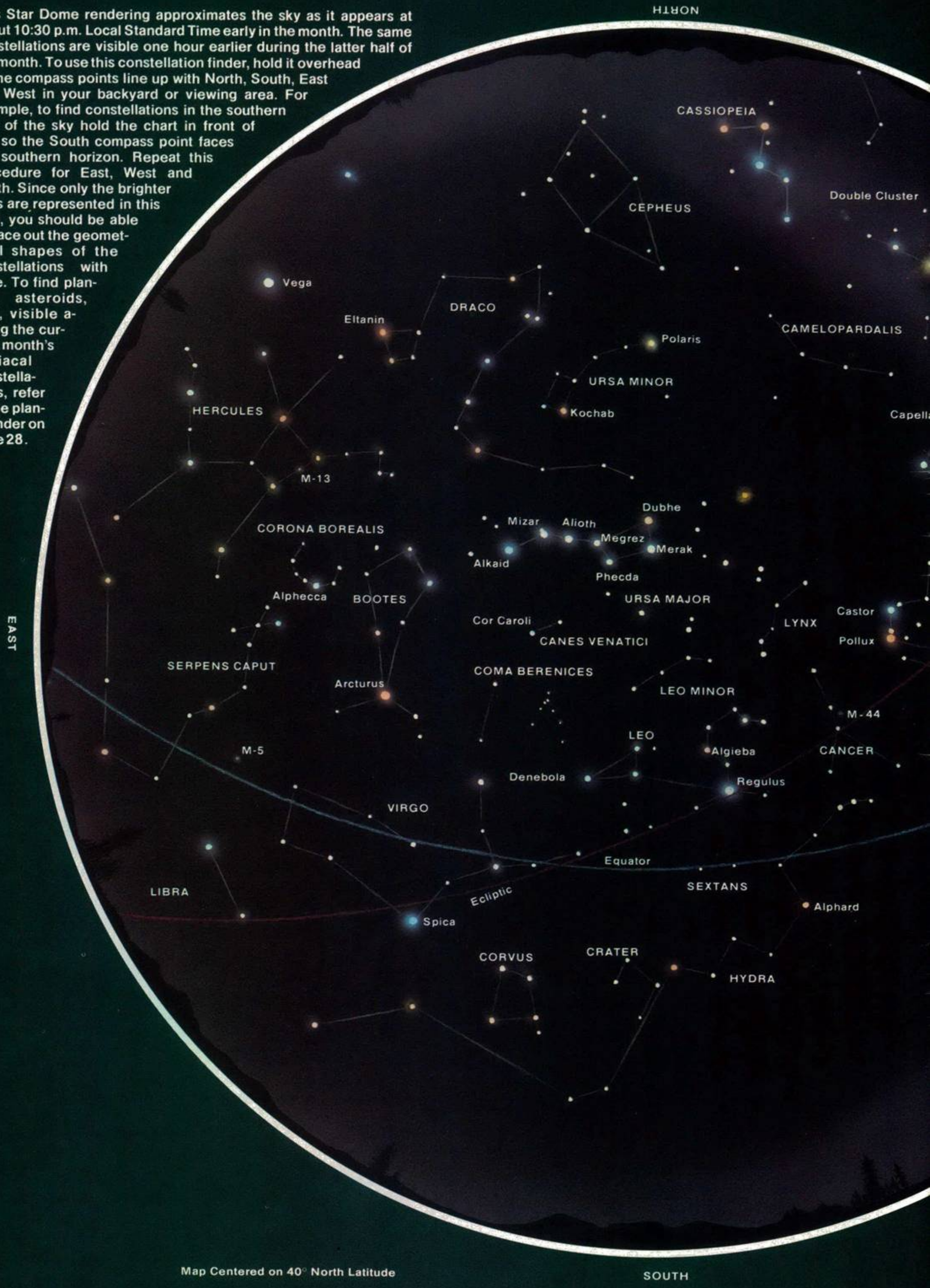
If you look closely at Mizar, you'll notice a tiny star near it, making Mizar a naked eye double. This companion is Alcor, and the two stars were once regarded as an eye test of sorts; if a person could separate the two, his eyesight was considered normal. Actually, this "test" really isn't that difficult to pass, as evidenced by Alcor's fame in star mythology of the past. For example, a delightful German story relates that the giant Orwandil stayed outside too long and froze one of his toes; the giant howled in pain so long and so loud that the god Thor, in desperation, broke the toe off and threw it at the middle horse drawing the wagon (as the Germans thought of the Big Dipper), where it remains to this day.

At the end of the handle lies Alkaid (Eta Ursae Majoris). An alternative name for this star is Benetnasch; both words are derived from the Arabian Ka'id Banat al Na'ash, the chief of the mourners. In Arabian folklore, the stars in the Dipper's bowl formed the coffin of a prince; the stars in the handle were the hero's three daughters following the bier in mourning.

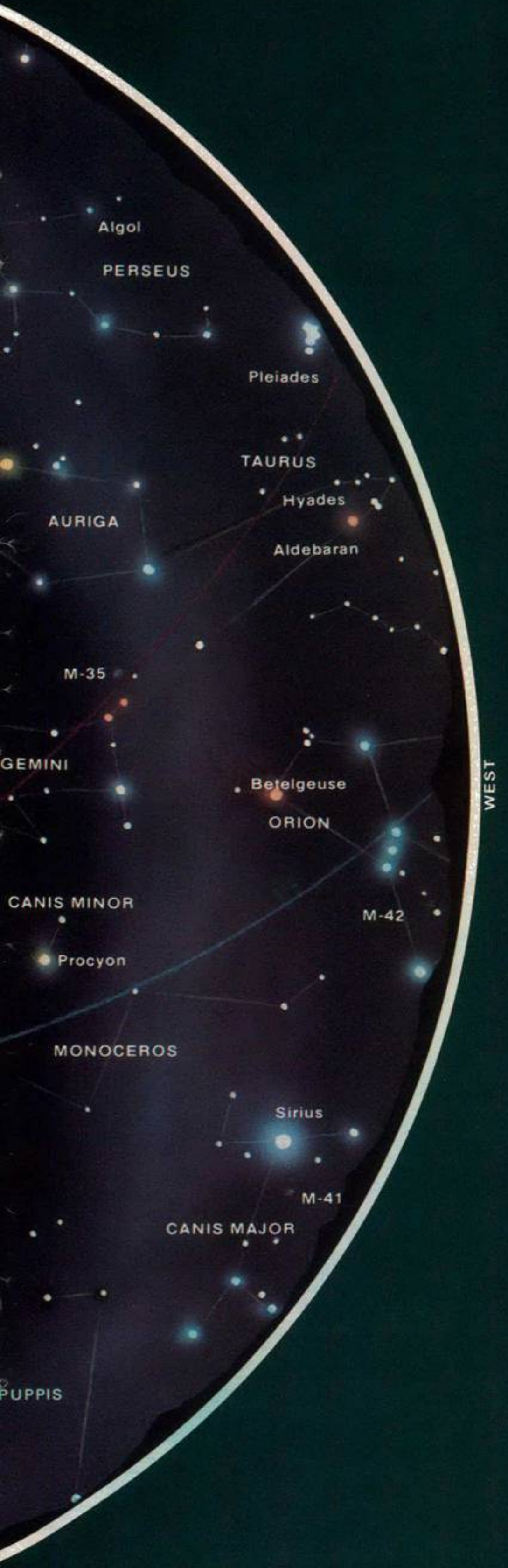
Alkaid itself is the most distant (210 light-years) of the seven stars. Its magnitude is 1.87, and it is a blue main sequence star of class B3.

As we glance over these statistics, we notice that no less than five of the Dipper stars belong to the same spectral class and are about the same distance away. Does this mean that these

This Star Dome rendering approximates the sky as it appears at about 10:30 p.m. Local Standard Time early in the month. The same constellations are visible one hour earlier during the latter half of the month. To use this constellation finder, hold it overhead so the compass points line up with North, South, East and West in your backyard or viewing area. For example, to find constellations in the southern part of the sky hold the chart in front of you so the South compass point faces the southern horizon. Repeat this procedure for East, West and North. Since only the brighter stars are represented in this map, you should be able to trace out the geometrical shapes of the constellations with ease. To find planets, asteroids, etc., visible among the current month's zodiacal constellations, refer to the planet finder on page 28.


NORTH
CASSIOPEIA
CEPHEUS
Double Cluster
Vega
DRACO
Eltanin
Polaris
CAMELOPARDALIS
URSA MINOR
Kochab
Capella
HERCULES
M-13
Dubhe
Mizar
Alioth
Megrez
Merak
CORONA BOREALIS
Alkaid
Phecda
Alphecca
BOOTES
URSA MAJOR
Castor
Cor Caroli
LYNX
CANES VENATICI
Pollux
SERPENS CAPUT
COMA BERENICES
Arcturus
LEO MINOR
M-44
EAST
LEO
M-5
Algieba
CANCER
Denebola
Regulus
VIRGO
Equator
SEXTANS
LIBRA
Ecliptic
Alphard
Spica
CORVUS
CRATER
HYDRA
SOUTH

Map Centered on 40° North Latitude



Map by Adolf Schaller

five stars are related in some way? Indeed it does; the five are traveling together through space, and are part of a large cluster of stars through which our sun is currently passing. (Sirius, the brightest star in our skies, is also a member of the group.) Dubhe and Alkaid, however, do not belong to the cluster and, in fact, are moving in different directions. Over the centuries, the Dipper's shape is slowly being destroyed as its stars move along their various paths through the void.

Although it's so famous, the Big Dipper doesn't form a constellation by itself, but instead is just a part of Ursa Major, the great bear. Ursa Major is an immense group, the third largest constellation in our skies, and swarms of galaxies are located within its borders. The neighboring groups of Canes Venatici, Leo Minor and Leo are also hosts to many galactic "tenants".

Many of the constellations in this section of the sky represent meat-eating animals: Ursa Major the great bear, Ursa Minor the little bear, Leo the lion, Leo Minor the little lion, Lynx the lynx, and Canes Venatici the hunting dogs — not to mention nearby Draco the dragon. It was for this reason that H.A. Rey, in **The Stars** (his classic introduction to the night sky), referred to this area as "Carnivores' Corner". The name is certainly apt, and provides a convenient handle by which we can remember these constellations.

Except for the Big Dipper, Leo has the most prominent configuration of any of the carnivores — or, indeed, of any of the spring constellations. The lion's head, mane and forelegs are represented by the sickle — a group of six stars that bears a resemblance to that implement — while a triangle of stars a few degrees farther east marks Leo's hindquarters.

To the Greeks, Leo was the Lion of Nemea that fell to Earth from the moon and ravaged the country until it was killed by Heracles. The lion's hide was impervious to every weapon used against it, and Heracles finally lifted the huge beast in his hands and strangled it. He then removed the hide (the Greeks didn't say how; it was doubtless quite a job), and wore it thereafter.

In Assyrian times (about 2000 B.C.), the summer solstice was located in Leo, and the sun's properties of life-giving heat and light became associated with both the animal and the constellation. Some Assyrian cylinders depict a fight between the lion and a bull; the conflict signified the defeat of darkness by light. Closer to our own time, Christians of the Middle Ages thought Leo was one of the lions in the den where the prophet Daniel was imprisoned.

First magnitude Regulus is the brightest of Leo's stars, shining at 1.36. Leo also has two stars of second magnitude. Denebola (Beta Leonis), in the triangle, is 2.14; name and star both signify the lion's tail. Algieba (Gamma Leonis) in the sickle is a double with a combined magnitude of 1.99. The star is on the lion's mane, the Latin word for which was "juba"; it's likely that Algieba is an "Arabianization" of this word.

Leo Minor, a small dim group just north of Leo, was introduced into the sky by Hevelius (see Star Dome, February 1977), who gave it its name because it was "of the same nature" as the adjoining constellations. Whether Hevelius meant it to be the cub or merely the smaller companion of Leo is unknown.

Close-Up

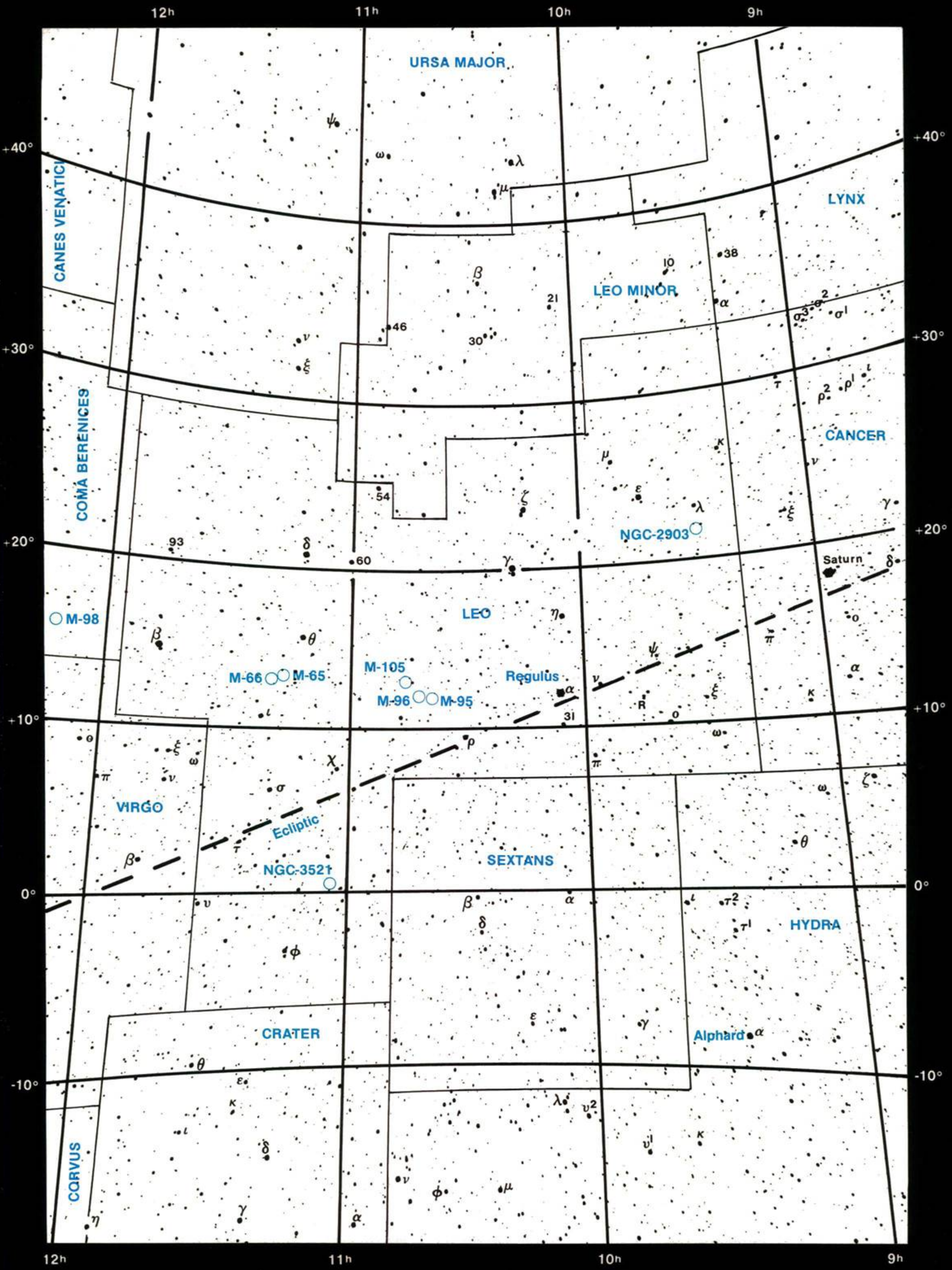
Leo/Leo Minor Region

Spring's long-awaited arrival is accompanied by an annual rebirth of interest in nature — not only on Earth, but in the sky as well. With the chilly nights of March giving way to milder April evenings, observers are encouraged to spend more time outdoors under the clearing spring skies.

Harbinger of the spring constellations is Leo the lion, together with its adjacent precinct Leo Minor. The former is an impressive 12th in order of size among the 88 constellations, and is heavily stocked with wonders as our table of objects indicates. The latter group ranks but 64th in sky area. Although peppered with faint galaxies and double stars, none are really outstanding enough to rate a place in our showpiece roster. Nevertheless, don't ignore Leo Minor. Telescope users who delight in explorations away from the "beaten track" will find this region an alluring adventure field on dark nights.

Leo is a splendid zodiacal constellation, with its star pattern (closely resembling its namesake) sprawled high across April's southern meridian. Lying directly in the path of the ecliptic is Leo's first magnitude luminary, Regulus — frequently occulted by the moon in its never ending eastward journey around the sky.

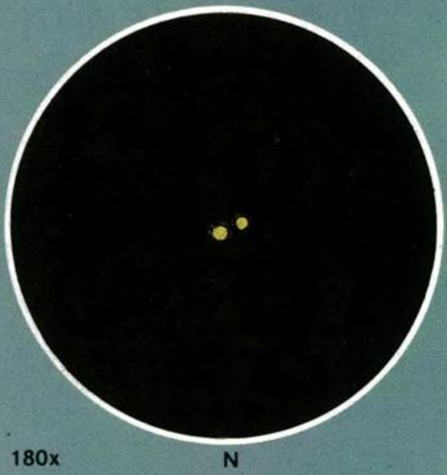
This month's region is noted both for its striking pairs of stars and its unique pairs of distant island universes. Leo's galaxies require a telescope for proper viewing, but some of its double stars are bright and wide enough to be seen in binoculars. One such pair is Zeta (ζ) in the well-known sickle. Zeta is often confused by novices with the beautiful telescopic double Gamma, which lies just below it. Zeta Leonis consists of fourth and sixth magnitude suns a roomy five min-


12h
11h
10h
9h
+40°
+30°
+20°
+10°
0°
-10°
URSA MAJOR
CANES VENATICI
LYNX
LEO MINOR
COMA BERENICES
CANCER
NGC-2903
Saturn
M-98
LEO
M-66
M-65
M-105
M-96
M-95
Regulus
VIRGO
Ecliptic
NGC-3521
SEXTANS
HYDRA
CRATER
Alphard
CORVUS

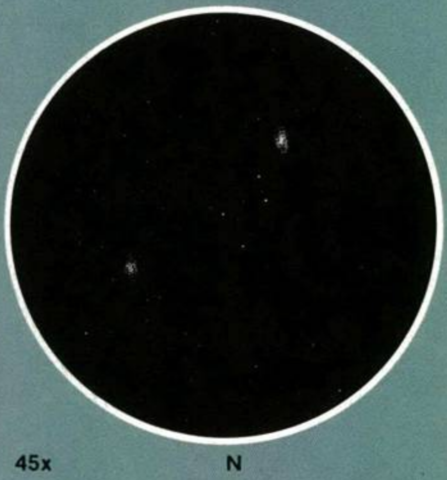
Photograph by Brad Wallis and Robert Provin/Map by Richard Berry utes of arc apart. There is also a fainter star in the same field to the south.

Another neat binocular duo is Tau (τ) Leonis, situated beneath the lion's hindquarters. Locating it offers good practice in the technique known as "star hopping". Begin by setting on second magnitude Delta (δ), and then "walk" your way southward to Theta (θ), Iota (ι), Sigma (σ) and finally Tau.

Gamma Leonis



M-65 and M-66



Top: Gamma Leonis is a pair of golden yellow stars separated by a tight 4.3 seconds of arc. The two stars shine at magnitudes 2.6 and 3.8 and are in slow orbital motion about each other. This drawing shows Gamma as it appears through a three inch refractor at 180 power; the field of view is about 15 minutes of arc. Bottom: M-65 (at lower left in this sketch) and M-66 are a bright pair of galaxies, similar in size and brightness, that lie a few degrees south of Theta Leonis. Both are spiral galaxies, and their central condensations are visible in this view through a four inch reflector at 45 power. The field of view is about one degree. Drawings by James Mullaney.

This fifth and seventh magnitude combo is separated by 90 seconds, and their tints have been described as lemon and pale blue.

To fully experience the lure and excitement of this region, telescopic scrutiny is necessary. We begin this month's survey in nearby interstellar space and end it within the mysterious depths of intergalactic darkness.

Regulus

The leader of Leo is 1.3 magnitude Regulus, marking the lion's heart at the bottom of the sickle's handle. (Some prefer to view this familiar figure as a mirror imaged cosmic question mark hanging eternally over us in the sky!) This lovely star is visible for eight months out of the year, and is a warming sight when seen rising in the east at winter's end.

Barns called this object "a noble sun". It is a blue-white main sequence star of spectral type B7, lying 84 light-years from us — therefore being the nearest of Leo's showpieces. Smyth described its hue as "flushed white".

Regulus has an eighth magnitude companion 177 seconds northwest of it; both stars are drifting through space together. Olcott rated this a difficult object in a three inch telescope even though it can be glimpsed in binoculars. Webb wrote that the small star "affords a beautiful contrast" with the primary, although he was referring here to its magnitude difference rather than its color.

The companion's color seems to have some strange, nondescript hue — usually given as white but with uncertainty. An intriguing comment about this object was made long ago by famed astronomical historian Agnes Clerke. She said this star's color was "seemingly steeped in indigo" — a curious remark which we should try to confirm for ourselves. What heavenly tint do you assign to the companion of Regulus?

Selected Objects — Leo/ Leo Minor Region

Object	Type	Mag.	Size/ Sep.	R.A. (1950) Dec.	
NGC-2903	Sp	9.1	11'x5'	09^h29^m	+21°44'
* R Leonis	V:313d	5.4-10.5	—	09^h45^m	+11°40'
* α(Alpha)	★ 2	1.3,7.6	176"	10^h06^m	+12°13'
* γ(Gamma)	★ 2	2.6,3.8	4"	10^h17^m	+20°06'
* M-95	Sp	10.4	6'x4'	10^h41^m	+11°58'
* M-96	Sp	9.1	5'x4'	10^h44^m	+12°05'
M-105	El	9.2	2'x2'	10^h45^m	+12°51'
54 Leonis	★ 2	4.5,6.3	6"	10^h53^m	+25°01'
NGC-3521	Sp	9.5	7'x4'	11^h03^m	+00°14'
* M-65	Sp	9.3	8'x2'	11^h16^m	+13°23'
* M-66	Sp	8.4	8'x2'	11^h18^m	+13°17'
ι(Iota)	★ 2	4.1,7.0	1"	11^h21^m	+10°48'

* Detailed in Close-Up

★2 = Double Star
Sp = Spiral Galaxy
El = Elliptical Galaxy

V:#d = Variable Star, period (days)
Mag. = Magnitude
Sep. = Separation

Gamma (γ) Leonis

Nearly twice as far away as Regulus lies one of the finest binary systems anywhere in the sky. This is second magnitude Gamma Leonis, the bright star at the bend in the sickle. Also known as Algieba, this beautiful golden duo was discovered by Sir William Herschel in 1782.

Its 2.6 and 3.8 magnitude suns are in slow orbital motion about each other over an uncertain period of at least 600 years. As a result, both the position angle and separation are increasing ever so slightly from year to year. Their present values are 123 degrees and 4.3 seconds. These figures are from current measures by Charles Worley (one of the few remaining visual observers of double stars in the world today).

Closest approach of the two stars (0.4 seconds) occurred in 1741, just prior to their discovery. Maximum separation of 4.6 seconds is predicted for the year 2063 A.D. The actual average space distance between them is 130 astronomical units or 17 light-hours (about twice the diameter of our solar system). This actual separation was calculated by the noted Belgium astronomer Jean Meeus. Information like this helps us to more fully appreciate what we are seeing at the eyepiece.

Gamma Leonis is a magnificent sight in even the smallest of telescopes — especially at high power in good seeing, as our drawing of the view in a three inch refractor indicates. It is split nicely at 100 power but its duplicity is evident with as little as 30 power to an experienced eye.

Most observers see both the members of this pair as golden yellow in color. Other hues, however, have frequently been reported. Herschel called the stars white and reddish white, while Webb logged them during different years as gold-greenish red, yellow-greenish yellow, and yellow-deeper yellow. Barns gave a consistent orange and pale yellow. Pickering included Gamma in his famous roster under "White Double Stars", but added:

"Both components yellow rather than white."

This pair's tints do seem to vary from night to night, probably because of atmospheric effects. As is the case with most bright pairs, these hues are more definite in small apertures than in large ones. A greenish cast to the companion can often be seen in two to four inch telescopes, but both stars look the same in bigger instruments. Their actual spectral types are K0 for the primary and G5 for the companion.

The great astronomer Otto Struve long ago called Gamma Leonis "one of the finest double stars in the northern sky" — and Struve had personally examined thousands of them! Olcott wrote: "It is best observed when it is not quite dark, or in moonlight." He gave the colors as yellow and green in his three inch refractor.

About a half degree south of Gamma is an interesting field star that bears watching. This is fifth magnitude 40 Leonis — an object suspected by some early observers as being a variable star, but never confirmed as such.

R Leonis

After a session at the eyepiece, puzzling over the tints of Gamma Leonis, next try an object whose color is both striking and unmistakable. This is the vivid red Mira-type variable star, R Leonis. Located five degrees west and slightly south of Regulus, R attains nearly fifth magnitude at maximum light and can be glimpsed with the unaided eye. However, at minimum it drops well below 10th magnitude — too faint for binoculars and near the limit of a three inch telescope. Its period is a well-established 313 days, and a maximum at magnitude 5.8 is predicted this year for April 1 — just in time for this month's Close-Up!

R Leonis is a giant pulsating sun that not only varies in its light output, but also its spectral type (from M7 to M9) during its cycle. Barns called it "a fiery, pulsating beacon"! Webb rated it as "one of the finest of its mysterious class, deserving a special investigation", and mentioned that certain red stars like R appear hazy when near minimum light. Can you confirm this?

The most complete description of this celestial stoplight is that given by Hind (of Lepus' "crimson star" fame): "One of the most fiery-looking variables on our list — fiery in every stage, from maximum to minimum, and is a really fine telescopic object in a dark sky, about the time of greatest brilliance, when its color forms a striking contrast with the steady white light of the sixth magnitude (star 19 Leonis) a little to the north."

We are presented with an excellent opportunity in April to see this event for ourselves. Don't let it slip by unobserved!

M-95 and M-96

Behind Leo's starry framework lurks an unsuspected cosmic wilderness populated with remote galaxies awaiting our attention. Two of the best, M-95 and M-96, are a pair of spirals located in the lion's body. You can pick them up in your telescope by sweeping with a low power eyepiece nine degrees east of Regulus on a dark transparent night.

Both appear round and are fairly large and bright for galaxies. M-95 shines at 10th magnitude and measures about six by four minutes of arc in extent. M-96 is a magnitude brighter and five by four minutes in size. Some observers feel these objects are more closely matched in brightness than these figures suggest.

You can see these galaxies in a three inch telescope at 45 power on a good night. They are easy objects in a six inch reflector and beautiful sights in larger amateur instruments. A one degree eyepiece field just includes both of them, but some observers prefer to view them separately, each centered at the middle of the field. M-96 is the brighter and easier to see of the two; M-95 is found a degree to the east.

Webb called M-96 a "very bright nebula" but said nothing about M-95, only listing it. Barns described this galactic duo with his usual enthusiasm: "A nest of nebulae! Two fairly bright, with starry centers, others fainter but interesting, in a region scarce of bright stars. . . . Worth many adventures." His observations were made with a home built 10 inch reflector.

One of the neighboring objects mentioned by Barns is M-105, a small ninth magnitude elliptical system just two minutes of arc in diameter. It lies about a degree northeast of M-96 amid a clump of faint galaxies.

Both M-95 and M-96 are at the same distance from our Milky Way galaxy — about 11 million light-years. They appear to form a physical pair gravitationally linked together — a kind of colossal, scaled-up version of a double star! The soft glow of their countless suns beckons the observer from across vast expanses of space and time.

M-65 and M-66

We end our survey of this month's far-flung region with another distant pair of galaxies. These are M-65 and M-66, considered by many as the best galaxies in Leo. They lie under the lion's hindquarters, midway between the stars Theta and Iota, and are bright enough to be picked up in a good finder.

M-65 is listed as 9.3 magnitude, and M-66 as 8.4; both measure an elongated eight by two minutes of arc in extent. These spirals are brighter and much closer together than M-95 and M-96, lying about 20 minutes apart in roughly a north-south direction. Both fit nicely in a one degree field and are a captivating sight in four inch and larger telescopes, as our drawing shows.

Olcott, strangely, did not mention either this pair of galaxies or M-95 and 96. Barns described M-65 and M-66 as "Very curious and mystifying. Worth diligent study." Webb went further: "Two rather faint objects, elongated visually in different directions, in a low powered field, with several stars. M-66 rather the larger and brighter." Smyth thought M-65 appeared larger than M-66, and saw them elongated in the same direction. D'Arrest simply commented that M-66 was "magnifica".

Some modern observers see M-65 as brighter than M-66, although the reverse is actually true. In such a case, correct identification of these objects is especially important. Those using star diagonals on a refractor or a catadioptric telescope should note that north and south are erect but east and west are reversed (a mirror image). Thus their view will not match the orientation of our drawing or published field charts of this pair.

Despite such technicalities, these remote star cities are well worth scrutiny by the visual observer. Their spiral arms are tightly wound and not obvious, but there is still much to see and contemplate. M-66, for example, has an irregular "curdled" appearance, reminding some more of a diffuse nebula than a galaxy.

A number of other faint galaxies lie near M-65 and M-66, including NGC-3628, an edge-on spiral to the north of the pair. Another is NGC-3593, a spiral just over a degree west of them. Both of these objects shine at 11th magnitude and can be seen in four inch and larger instruments.

Like its fainter and wider copy to the east, the M-65/M-66 system may be physically associated, for both galaxies lie roughly at the same distance from us — in this case, between 9 and 10 million light-years. It also appears that each of the pairs we have examined are simply the brighter members of actual clusters, since they are surrounded by other galaxies. Instead of two pairs of island universes, we are actually dealing with a double cluster of galaxies within the same constellation.

Nature seemingly prefers to work in pairs and groups — whether it be atoms, stars, galaxies or even people. The splendor of this month's region shouldn't be kept only to yourself. Invite a friend to join in on your next observing session so that he or she too can experience the thrill and excitement of astronomy. As an old English proverb states: ". . . a joy that's shared is a joy made double."

Welcome to the Great Nebula in Orion.

Exposure: 45 minutes on chilled High-Speed Ektachrome

Now Meet the Telescope that Took the Picture.

The World's Best-Selling Modern Telescope.
The Celestron 8
(Base Price: $790)

Ask for Your Free Color Catalog.

Celestron International
2835 Columbia St., Box 3578-AM
Torrance, Calif. 90503, U.S.A.

Celestron